University of Alberta

Cookies Enriched with Barley Protein Concentrate

by

Sandra Gail Spence

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Feral Temelli

Wendy Wismer

Thava Vasanthan

Ellen Goddard

Date: _____

To my Auntie Marion who could find humor in any situation; thanks for all the laughs Auntie. To Basil, who is sadly missed and always loved.

Abstract

Demonstrated health benefits of barley led to fractionation processes and utilization of various fractions. The objective of this research was to incorporate barley protein fraction into cookies to enhance barley consumption. Cookies were prepared with barley protein concentrate at 0-45% flour substitution and characterized using instrumental and sensory techniques. With substitution level, protein content of cookies increased ($p \leq 0.05$) while instrumentally determined hardness increased and spread decreased. Trained sensory panel found that aroma, saltiness, cereal flavour, chewiness, cohesiveness, toothpack and mouthcoat increased ($p \leq 0.05$), while sweetness decreased with increased substitution. Consumer panel found that 15% and 20% substitution produced cookies similar ($p > 0.05$) to the control. Another consumer study compared barley, oat, and soy protein concentrate cookies at 20% substitution. Attributes (appearance, aroma, flavour, texture, overall acceptability) increased for barley, after providing nutrition information. Barley protein concentrate was successfully incorporated into cookies; however, further formulation and better understanding of consumer acceptability is required.

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1. INTRODUCTION AND THESIS OBJECTIVES

Canada and specifically Alberta are major producers of barley, which is predominantly used as livestock feed or in the malting and brewing industry. A mere 5% of barley production in Canada is utilized in various food products, such as baby food/cereal, breakfast cereal, and some baked products, where the most common form of barley is pearled barley for soups, stews or rice extenders. Barley is a rich source of beta-glucan, Vitamin E (tocopherols), and protein. Despite all the positive health benefits of such components, barley is underutilized as an ingredient in human food products.

The functional foods are everyday foods with health benefits beyond basic nutrition. Functional food market is driven by scientific research establishing the relationships between various food components and health benefits and by consumers who are seeking food products for additional health benefits. On the other hand, isolation of various barley components for functional ingredients is not fully developed yet.

Cereals are mainly consumed for their carbohydrate or dietary fibre and not necessarily as a sole means of protein due to the fact that majority of cereals are limited in essential amino acids mainly, lysine, methionine, and threonine. In general, people in North America and other developed nations consume protein in excess of recommended amounts, mainly in the form of animal protein. Cereals can provide a source of protein at a lower quality, while still providing adequate nutrition. The amino acid composition of barley protein concentrate has been reported to be similar to that of soy with the

exception of lysine being the first limiting amino acid for barley. Functional foods could play a major role for increased consumption of cereal grains.

Grain fractionation processes for isolation of functional ingredients like beta-glucan have been developed; however, the cost is high for extracting a single component. Therefore, it would make such processes more economically feasible if applications for all barley grain fractions such as beta-glucan, lipids, starch, and proteins were developed. There is potential for food product development in terms of functional ingredients from these various fractions. Food product development work has been completed on incorporating barley beta-glucan as an ingredient in a beverage and low-fat breakfast sausage. To date food product applications of barley protein concentrate or the physical and sensory characteristics of such products have not been studied. In contrast, there have been numerous studies conducted on the physical and functional properties of soy protein concentrates along with corresponding food product development. Therefore, the overall objective of this research was to enhance utilization of barley, specifically concentrated barley protein obtained by grain fractionation, targeting high-value functional ingredients.

The specific objectives of this thesis were:

1. to develop a bakery type product such as a cookie with concentrated barley protein and to characterize its physical and sensory attributes (Chapter 3), and

2. to assess consumers response to cookies fortified with concentrated barley protein in comparison to cookies fortified with concentrated oat and soy protein (Chapter 4).

2. LITERATURE REVIEW

Cereals are nutritionally dense and supply carbohydrates and protein along with a variety of vitamins, minerals, and micronutrients. Gregory and others (1990) estimated that cereal based foods provide roughly 20% of protein, and 30% of dietary energy along with 45% of dietary fibre of the adult diet. Even though cereals provide excellent source of nutrients the main drawback is that cereals tend to have inherently lower amounts of the essential amino acids in particular lysine and threonine.

For human consumption and some animal feeds cereals require some type of processing to allow increased bioavailability of nutrients. Typically, cereals undergo mechanical processing such as milling wheat into flour or abrasive processing such as pearling of barley. These mechanical processes increase surface area, which in turn allow easier break down through enzymatic digestive process. Thermal processing such as baking disrupts the starch and protein components leading to better absorption through the gut (Alldrick and Hajselova 2002). The physico-chemical properties and structure of carbohydrates and proteins are affected by mechanical and thermal processing. Therefore, to develop nutritionally enhanced cereal based foods, food scientists are faced with the challenges of using production methods conducive to enhancing nutrition as well as satisfying consumer's demands for healthy diet.

Functional foods can be simply described as foods designed to meet the consumers' aspiration of improving health through diet (Alldrick and Hajselova 2002).

As socio-economics change and the population ages coupled with increasing health care costs of this aging population and diet related diseases the demand for functional foods will escalate as consumers want to take charge of their health issues through diet. Consumers interested in such functional foods require public information based on scientific evidence on the effectiveness of these products. One way to inform the public at large is through labeling. Nutrition facts allow consumers a way of knowing what they are consuming in particular food products. Health claims allow food processors a means of informing consumers the benefits of consuming particular food products that are enhanced or fortified with specific nutrients. Cereals such as barley and oats are ideal ingredients to produce a wide variety of functional foods.

2.1. Grains

2.1.1. Barley

Barley, *Hordeum vulgare* L., has been cultivated as a cereal and used as a food source for approximately 10,000 years (Wendorf and others, 1979). Barley has a long history of food uses from gladiators in Roman times to barley grits in porridge and pearled barley in meat broths throughout Europe during the 1800's (Munck, 1981). The consumption of barley as a human food source declined as production of wheat increased. Presently, domestic animal feed and malt for the brewing industry are the principal markets for barley production. Only a small percentage of production (5% or less) is used in food formulations, including flour for bread and baby foods, pearled barley for soups or rice extender and as malt used as a food ingredients for flavour and colour

enhancement (Bhatty, 1986). According to the USDA economic research service the consumption of barley as flour, pearled barley and malt or malt extracts used in food processing is currently around 0.3 kg/capita/year (USDA, 2004).

Ranking of world cereal production by volume is as follows: wheat, rice, corn and barley. Canada is one of the world's largest producers of barley (Stats Canada, 2005). In Canada, barley production for the year 2004 was 13 million metric tonnes (Mt). Australia produced over 7 million Mt, close to half of Canada's production, while the U.S. was close to 6 million Mt for the same production year (FAO, 2005). In Canada, barley production is second to wheat. In 2004, China was the largest buyer of Canadian wheat for the sum of $185 million, purchasing just over 800,000 Mt, which is up from the previous year indicating they are a re-emerging market (Statistics Canada and Alberta Agriculture, Food and Rural Development, 2005). There was also a sharp increase in demand for export barley in the Chinese market (Stats Canada and AAFRD, 2005). Wheat production for Alberta in 2004 was just over 6 million Mt, while barley production was over 5 million Mt (Stats Canada and AAFRD, 2005), which is down 4% from 2003 and 3% below the 10 year average. Figure 2.1 compares cereal grains seeded area for Alberta compared to that for Canada for the year 2004 (Stats Canada, 2005). Alberta accounts for nearly 40% of the total seeded area of barley in Canada.

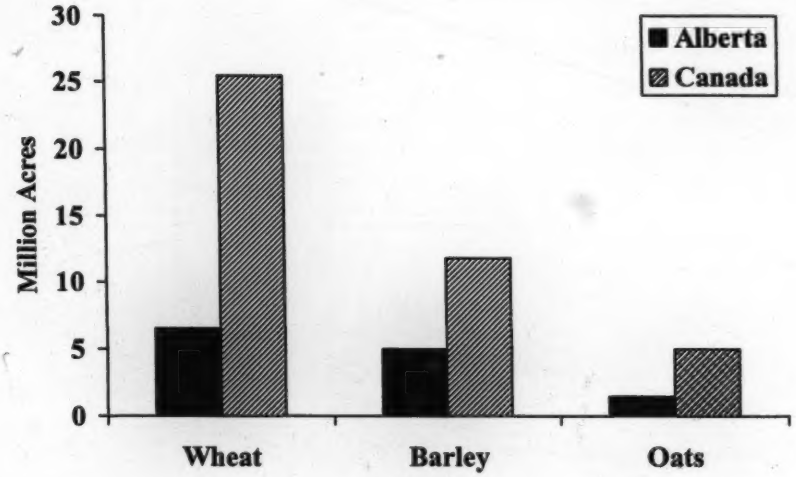

Figure 2.1 Seeded area of field crops in Alberta and Canada for the year 2004 (Adapted from Stats Canada, 2005).

Canada's largest importers of feed barley are Saudi Arabia at 5,800 Mt and Japan at 1,300 Mt (Canadian Wheat Board, 2005). Canadian barley supply in 2004 was 15.4 million Mt of which, 10.5 million Mt was used for the domestic market and of that 9.7 million Mt was used as feed. Exports accounted for 1.8 million Mt and of that 0.2 million Mt was used as feed, 0.9 million Mt for malting, and 0.7 million Mt for malt (Canadian Wheat Board, 2005). In summary, these stats indicated that Canada uses approximately 69% of the barley it produces in the domestic market. Of the domestic market 90% is for animal feed and approximately 8 to 10% for malting (Nilan and Ullrich, 1991).

Figure 2.2 illustrates a typical barley grain and corresponding seed structure. There are three main tissues of barley grain, the bran, the inner endosperm, and nucleus.

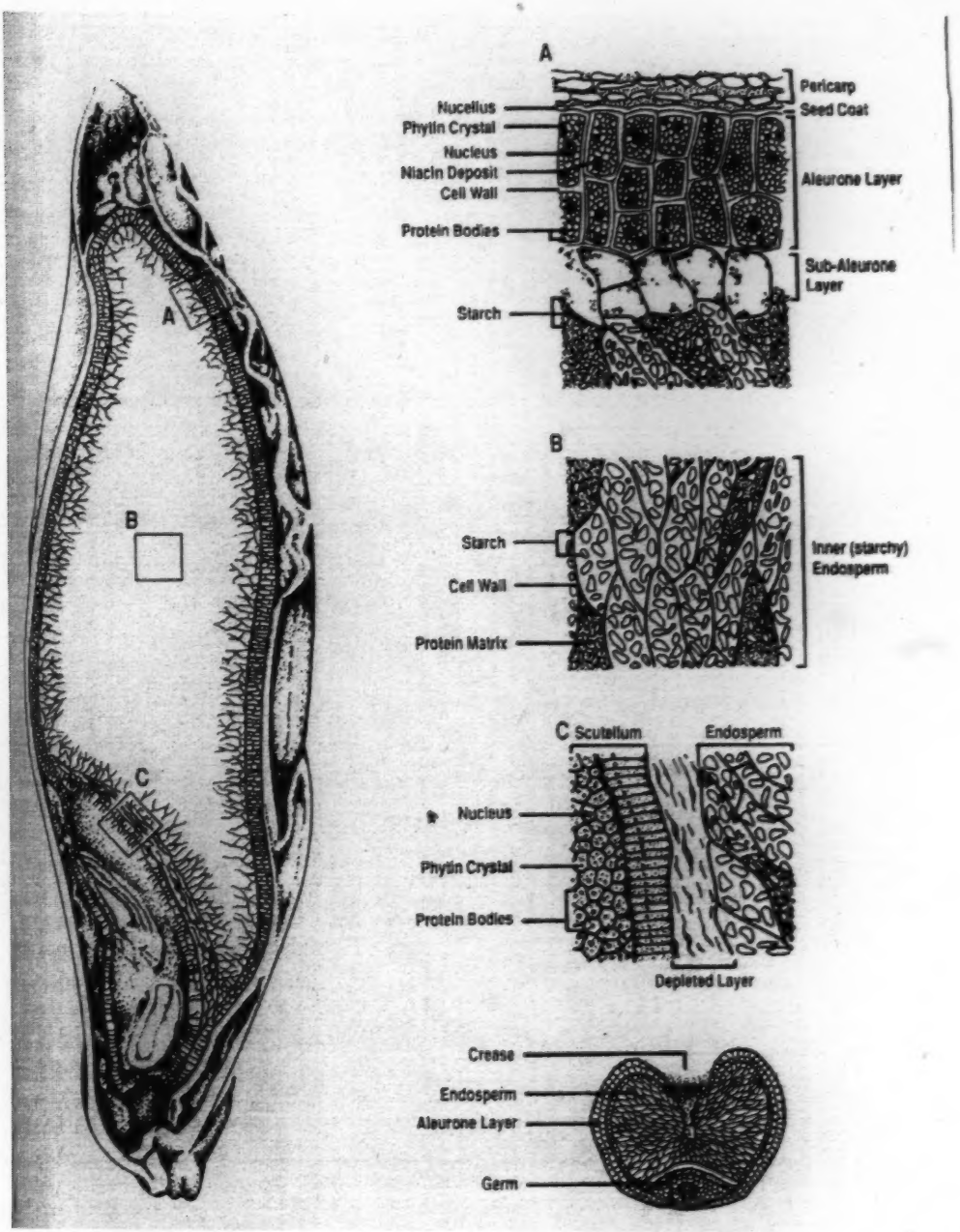

Figure 2.2 Structure of barley kernel. (Adapted from Newman and Newman (1991), with permission Cereal Foods World).

The bran layer contains the pericarp, seed coat and the sub-aleurone layer. The inner endosperm is made up of mainly starch granules that are trapped within a protein matrix; however, the nucleus section carries more protein bodies.

Table 2.1 contains the overall chemical composition of barley grain, keeping in mind that the grain composition is dependent on environmental conditions and genetics. Barley typically has a protein content between 8-13%. The starch content of the barley kernel is 63-65% and total carbohydrates range between 78-83% which include starch, sucrose, beta-glucan and cellulose. Beta-glucan content of barley ranges from 2 to 11% and accounts for 70-75% of the endosperm cell wall (Macgregor and Fincher, 1993). Beta-glucan is a linear chain of glucose molecules with 1:3 ratio of beta – (1-3) and beta – (1-4) links. This configuration makes beta-glucan a flexible molecule that is soluble in water (Woodward and others, 1983). Beta-glucan has several functional properties including water binding, emulsion stabilization, gelation and viscosity. Beta-glucan is a soluble dietary fibre shown to have therapeutic effects such as regulation of blood glucose and reduction of serum cholesterol levels (Klopfenstein and Hoseney, 1987; Newman and Newman, 1991; Wang and others, 1992; Wang and others, 1997; Yokoyama and others, 1997; Hecker and others, 1998). Lipids make up 2-3%, minerals 2% and other components 5-6% of the barley protein grain. Kent (1975) reported that the bran contains approximately 20% of the oil and minerals as well as 10% of the sugars. Barley is also high in the vitamin-E family of compounds (tocopherols and tocotrienols), B complex vitamins, and soluble and insoluble fibre (Newman and McGuire, 1985).

Table 2.1 Overall typical chemical composition of barley, oat, and soy[1]

	Barley	Oat	Soy
Carbohydrates	78-83	64-70	34
Beta-glucan	2-11	2.7-5.4	--
Lipids	2-3	3-12	21
Protein	8-13	10-12	40

[1]% w/w, dry weight basis.

2.1.2. Oat

Oats, *Avena sativa* L., includes cultivated, wild, and weeding polyploidy species. Cultivated oats are presumed to be derived from wild oats by farmers in the Middle East and Europe approximately 4,500 years ago (Murphy and Hoffman, 1992). Oatmeal has been consumed throughout Europe, typically among the poor. Oats were introduced to North America by Spanish explorers who brought oat grain to feed their horses (Coffman, 1977). However, where there were large Scottish settlements oats were used to feed cattle and horses, but also significantly contributed to the human diet (Burnette and others, 1992). Ferdinand Schmacher was known as the Oatmeal King, as he promoted oats for relief of stomach discomforts to the American population (Lockhart and Hurt, 1986). Schmacher developed a tastier, easier to cook rolled oat, which appealed to the American housewife (Marquette, 1967). It was Crowell who used marketing techniques to create the first brand name cereal "Quaker" (Burnette and others, 1992). Today, several oat cultivars are grown either as feed for animals or for human consumption as a cereal. Consequently, oat has advanced from being strictly animal feed or human

stomach discomfort relief to an important ingredient in many foods ranging from cereals, and baked goods, to infant formulas.

Oat ranks sixth in world cereal production (Murphy and Hoffman, 1992). During 1980-1985, three-fourths of total consumption of world oat grain was for livestock feed (Burnette and others, 1992). Seventy five percent of oat grain is consumed as animal feed and 22% is for human food and seed production (Burnette and others, 1992). The majority of oat for human consumption in the U.S. and U.K. is in the form of rolled oats. U.S. industry sources estimate nearly 85% of oat is used as standard or instant oatmeal, while close to 15% is used in snack products or as oat flour (Hoffman and Ash, 1989). Food consumption of oat products that include rolled oats, ready to eat cereals, oat flour and bran according to the USDA economic research service is currently at 1.95 kg/capita/year. The highest consumption reported was in late 80's to early 90's , which topped out at 2.95 kg/capita/year (USDA, 2004). Oat food uses are ahead of barley, sorghum and other grains (Burnette and others, 1992). Due to their moisture retention properties, oat products can be used in bakery goods to keep baked goods fresh longer (Burnette and other, 1992).

Production of oats in 2004 for U.S. was 1.6 million Mt and Australia 1.4 million Mt. The largest producers of oats include Canada, U.S., Australia, the former Soviet Union, and Germany. Canada produces nearly three times as much as the U.S. or Australia at around 3.5 million Mt, while Alberta grew just over 800,000 Mt in the 2004 season (Stats Canada, 2005).

Oats compared to other cereals are higher in protein and fat. As shown in Table 2.1 composition of oat is protein 10-12%, fat 3-12%, fibre 12-14%, beta-glucan 2.7-5.4% (McCleary and Homes, 1985) and total carbohydrates 64%. Starch is the major constituent that is located in the endosperm. Lipids in oat are found in the bran and nucleus (Youngs and others 1977). Beta-glucan is more concentrated in the cell walls of the subaleurone region (Fulcher, 1986; Henry, 1987; Wood and others, 1989). 'Oat groats' refer to de-hulled oat grains or hull-less oat grains. Oat groats have the highest lipid content among cereal grains (Liukkonen and others 1992).

2.1.3. Soybean

The common soybean, *Glycine max* L. was developed from northern China (Dawn, 1993). Asian cultures have used soy extensively for centuries; Northern China reports using soy as a food source since the 11th century. In direct contrast, soy in North America has only been utilized for approximately 100 years and was initially used as hay and silage for animal feed. It was not until 1915 that processing of soybeans in the U.S. took place (Dawn, 1993) and was recognized as an economical source of vegetable oil. Recent technological advances have resulted in the use of soy being expanded from simply roasting and grinding soybeans to make soy flour to texturized soy protein used as meat substitute or meat analog products. Soy flour was used with minimal success in baked products because of "beany" flavour, chalky texture and taste. Many people have negative attitudes toward soy products because of perceived taste and texture differences. On the other hand, today soy protein is widely used by the military, school lunch programs, and in baby formulas as well as diet supplements in North America. The U.S.

military service extends ground beef by blending beef with re-hydrated granular soy concentrates, which has resulted in savings of $10 million annually. A study conducted in military dining facilities comparing 100% beef control to 20% soy extended ground beef showed no significant difference in product acceptability (Chou, 1982), thus clearly showing the possibilities of using soy along with cost saving and health benefits.

Soybean acreage in Canada has increased from 1,082 thousand hectares in 2001 to 1,207 in 2004 (Stats Canada, 2005). The majority of Canada's production is found in southern Ontario and southern Manitoba. Currently, Canadian production is not sufficient to meet requirements and up to 300,000 Mt are imported per year (Dawn, 1993). Canada produces less than 1% of the world's soybeans with the U.S. and China being the main producers (Dawn, 1993). In 2004, U.S. soybean production was 85 million Mt compared to Canada at only 2.9 million Mt, while Australia reported 74,000 Mt.

Soybeans are approximately 18 to 21% oil and the oil contains 40% linoleic acid and 8% linolenic acid. Table 2.1 compares soybean composition to that of barley and oat. Soybean oil uses range from industrial uses in paint and varnishes to plastics industry. In the food industry, soybean oil is used in margarine and shortening as well as salad oils. The protein content of soybeans ranges from 30 to 40% making it a valuable source of protein. Soybean meal is used as an additive for animal feeds.

2.2. Grain Fractionation

Fractionation processes for various plant materials have been developed over the years and are gaining in popularity as scientists discover the importance and high value

end uses of many components that at one time were discarded or used strictly for animal feed. To improve the nutritional and functional properties of cereals, extraction processes have been developed to concentrate valuable components such as gluten from wheat. Isolation of wheat gluten has lead to improved bread making properties and use of wheat in nontraditional settings such as in the meat industry for meat analogs. Soy is another prime example of how initially this plant material was only utilized for its oil and meal. Currently, with further fractionation soy is not only processed into oil and meal, but also several types of flour and proteins as well as minor component fractions for use in literally hundreds of products.

The fractionation process itself varies with starting material along with desired end products, but generally the plant material is milled, ground, or crushed and made into a slurry with a solvent. The temperature and pH of the slurry are adjusted to optimize extraction of specific components. Enzymatic treatment may also be incorporated to enhance the purity of product fractions. Industry standards define "concentrates" to have a protein content from 65 - 75%, while protein "isolates" are over 90% purity.

Soybean protein isolates or concentrates obtained through fractionation have been used extensively since the 80's. The main cereal protein that has been fractionated and utilized is wheat gluten, with little or no attention given to other cereals. However, barley and oat have received increasing attention due to their beta-glucan content and fractionation processes have aided in obtaining higher concentration and purity of this valuable component.

2.2.1. Barley

Fractionation of barley to isolate beta-glucan will not only increase the importance of barley as a crop, but also contribute to the value-added processing of cereal grains. Enhancing value-added processing in Alberta could increase economic value of barley and aid in the development of functional food products; for example, the utilization of barley flour in bread (Matz, 1991) and barley beta-glucan in orange flavored beverage and low-fat breakfast sausage (Bansema, 2000; Morin, 2001). Izydorczyk and others (2003) reported on optimizing roller milling of hulless barley to produce a fibre-rich fraction (FRF) high in beta-glucan as a functional food ingredient. They reported the potential incorporation of FRF into noodles and bread. Even though barley fractionation has been reported by Wu and others (1994), Bhatty (1995) and Temelli (1997), there is scarce information in the scientific literature regarding further development and industrial use.

Several researchers (Chen, 1970; Cluskey and others, 1973; Wu and Sexon, 1975, 1976; Wu and others 1976; Wu, 1978; Wu and others, 1979; Lekhi, 2004) have investigated alkaline extraction of protein concentrates from various cereal grains including barley, oat, wheat, triticale, corn, and rice bran. Protein purity and yield vary with extraction conditions. The most common conditions incorporate the use of NaOH as the solvent at a pH range of 9-12, while the precipitation of proteins occur at isoelectric pH of 4.5-5.5.

Osborne (1924) initially classified wheat proteins on the basis of solubility. Since then other researchers have attempted various extraction procedures to optimize the

separation of cytoplasmic proteins (CP) and storage proteins (SP). Shewry (1977, 1978) reviewed the techniques for separating barley proteins and identified three classes of hordeins based on molecular weight. Landry and others (1972) determined that glutelins possess two major protein types; one similar to albumins and globulins while the other not unlike that of hordeins. Methods of extraction for CP (albumins and globulins) are straightforward as compared to those of SP (hordein and glutelin).

Alkali extraction efficiency is based upon solvent type, concentration, and isoelectric pH to precipitate out proteins and is relative to the cereal grain under study. As compared to feed flour, protein concentrates acquired through alkali extraction are higher in essential amino acids. Wu and others (1976) depict that protein concentrates are bland in flavour, and low in ash, fat, and starch. Functionality of concentrates then depends on the extraction conditions, which will be reflected in end product quality results. The alkali process results in one concentrate containing all four types of proteins (albumins, globulins, hordeins, and glutelins) in varying amounts depending on the extraction conditions and isolelectric precipitation of all proteins. Lekhi (2004) reported on alkali extraction with bench top recovery of 66-74% with 70-82% protein concentration in the product. The main proteins in barley protein concentrate as obtained by Lekhi (2004) were hordeins and globulins.

2.2.2. Oat

Common steps in oat processing include cleaning, drying, de-hulling, steaming, and flaking. Approximately 180 kg of oat grain are needed to produce 100 kg of products

(Burnette, 1992). Products produced include steel cut oat groat, rolled oat, oat flour, and oat bran. Oat starch is isolated from oat groats or oat flour through conventional wet milling techniques. Because of the high levels of lipids and lipase activity the milling process whether wet or dry, is not easy. Liukkonen (1993) found that alkaline conditions (pH 8) in aqueous suspensions of oat flour eliminated hydrolysis of triglycerides and maintained free fatty acids levels. Cluskey and others (1976) reported extraction of protein concentrates from de-hulled oat with reasonable purity of 74-76%, but low yield (<22%).

2.2.3. Soybeans

Soybeans are cracked, de-hulled and then conditioned. The conditioned beans are then flaked through a flaking mill in-order to maximize oil extraction. Oil extraction from soybeans is done through solvent extraction. The refining process removes minor non-triglyceride components from crude vegetable oils thereby increasing the quality of oil. The nutritive value of soybean meal is increased when the trypsin inhibitor is inactivated through high temperature treatments.

Full-fat and de-fatted soy flour are made from de-hulled, toasted, and ground soybeans. Soy flours are finely ground soybean meal that contains approximately 48% protein. The protein concentrate is made by recovering the protein by isoelectric precipitation with aqueous acid, alcohol, heat or mixed organic solvents. Soluble proteins plus carbohydrates and salts are produced. Removal of water-soluble carbohydrates from soy flour prior to producing soy protein concentrates can also be carried out. These

concentrates are typically 70% protein and 4% fibre. Concentrates can be dried, or re-hydrated; they can be made into fibres, granules or flakes. There are several major advantages in using concentrates other than the obvious of increased protein. There is improved colour with concentrates and several functional advantages as well. Concentrates also have improved flavour, which refers to less "beany" flavour. In obtaining concentrated proteins non-digestible stachyose and raffinose are removed. These compounds are the primary cause of flatulence response; therefore, using concentrates will reduce the concerns of gas production in some individuals.

Soy protein isolates are prepared by extraction, purification, and re-precipitation of proteins; thus, yielding a product containing more than 90% protein. Waggle and others (1989) touted the use of isolates as having nutritional and functional as well as economical advantages.

A new technique for soy starts with soy protein concentrate or isolate rather than defatted soy flour. The soy protein is used in low temperature twin-screw extrusion. The final stage freezes the product instead of drying, resulting in a sticky residue for food preparation, which has improved flavour and untangled fibres that are better for meat texture (Harland, 2002).

2.3. Protein

Proteins are complex nitrogenous compounds made up of amino acids linked with peptide bonds. Amino acids all have the same general structure shown in Figure 2.3. The function and properties of a protein depend upon the sequence of amino acids. The basic

structure contains an acid group (-COOH), an amino acid group (-NH_2), a single hydrogen atom (-H) and a side chain (-R), which is different in every amino acid. Amino acids are considered nonessential if the body can synthesize the amino acids. Essential amino acids are ones that humans cannot make; therefore, they can only be obtained through the diet. The acid group and amino group make the links that form the polypeptide chains, while the side chains are responsible for physical characteristics like water binding. The side chains also influence the polarity (non-polar or polar) and acidity (acidic, neutral, and basic) through the type of group such as aromatic, cyclic, sulfur, or hydroxyl.

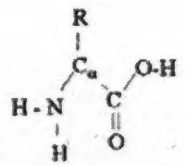

Figure 2.3 General amino acid structure

Proper folding of the amino acid chain is essential for function and each protein has its own unique folding pattern. Protein folding occurs through hydrogen bonding, ionic bonding, hydrophobic and other interactions between the side chains of each amino acid. There are four levels of protein structure; primary, secondary, tertiary, and quaternary. Primary protein structure is a linear chain of amino acids. Secondary structures are helices (i.e. alpha-helices) and pleated sheets (i.e. beta-sheets) due to attractions between side chains, whereas tertiary structures are helices and pleated sheets that are folded into compact domains. Quaternary structures are polypeptide subunits that

are joined into a complex structure. Consequently, a good understanding of protein structure and composition is necessary for manipulation to obtain desired functionality.

2.3.1. Protein nutritive value

The Recommended Dietary Allowance (RDA) for protein is 0.8 g/kg body weight for a healthy adult. Canada's Food Guide to Health Eating (CFGHE) recommends total daily energy intake to be provided by 15-20% from proteins, 50-65% from carbohydrates, and 20-30% from fat (Health Canada, 1992). CFGHE recommendation for the general healthy population ages 2 and up is 2-3 servings of meat and meat alternatives a day (Health Canada, 1992).

Energy is measured in kilocalories (kcals) where 1 g of carbohydrate yields about 3.75 kcals, whereas 1 g protein equals 4 kcals and 1 g fat gives 9 kcals. Total caloric needs and protein requirements are dependent on the age, sex, and physical condition of an individual. Protein through the diet supplies nitrogen and amino acids for the synthesis of body proteins.

Nutritional quality of proteins are determined by the amino acid composition, the bioavailability (digestibility), biological value of proteins and protein efficiency ratio. In North America, the average protein intake is above the recommended daily allowance due to the high consumption of meat and meat products. However, for vegetarians and populations in developing nations cereals are a major source of proteins. Cereal proteins are of low biological value, but can provide adequate amounts of protein (Pomeranz, 1987; Jansen, 1972). Cereals provide plenty of nutrients from carbohydrates, vitamins,

and minerals. Gregory and others (1990) suggested that cereal-based foods provide around 30% of dietary energy, over 20% of dietary protein and nearly 45% of dietary fibre in the adult diet.

Proteins are evaluated on either growth rate or assessment of the nitrogen. Osborne and Mendel (1924) proposed protein efficiency ratio (PER) as the weight gain supported per unit of protein ingested by rats. The biological value (BV) expresses how a particular protein can be utilized in the body. Breakdown of amino acids to release nitrogen is termed nitrogen digestibility (ND). Protein content is calculated by multiplying the amount of nitrogen measured by a factor of usually 6.25. The protein quality values including PER, BV, and ND of cereal grains, casein, eggs, and soybean are shown in Table 2.2. Eggs are used as the standard for PER. Barley has a high BV and PER with 82% nitrogen digestibility, which makes it desirable as a food source for human or animal nutrition. Barley's nitrogen digestibility is comparable to these other protein sources.

2.3.2. Grain proteins

Plant proteins account for 50-75% of total human dietary protein needs, while animal protein provides approximately 33% of this total. Most of the plant proteins come from cereal grains, pulses, and oilseeds. Where animal protein is not adequate or as in many developing nations plant proteins are the main sources of protein. Soybean and cottonseeds are utilized for protein isolates and concentrates more so than other seed bearing plants (Karakoltsidis and Constantinides, 1975).

Table 2.2 Cereal and oilseed protein quality

Protein Type	BV[1]	PER[2]	ND[3]	References
Barley	75	1.6 – 2.0	82	Bhatty (1993)
Oat	74	2.0 – 2.5	79	Lockhart and Hurt (1986)
Soy	--	1.8	90	Wilcke and others (1979)
Wheat	58 – 67	0.9 – 1.7	92	Nierle (1985)
Egg	95	3.5	88	Nierle (1985)
Casein	89	2.5	99	Bodwell (1985)

[1] BV=biological value (retained nitrogen/absorbed nitrogen)x100%.
[2] PER=protein efficiency ratio= weight gain by animal/amount of protein fed.
[3] ND= nitrogen digestibility (total nitrogen intake/total nitrogen remaining at the end of the small intestine)x100.

Chung and Pomeranz (1985) reported that the amino acid profiles of wheat, barley, oat, corn, and rice are similar; however, barley and oat amino acid profiles possess higher nutritive value. Cereals are first limiting in lysine and second limiting in methionine. Alldrick and Hajselova (2002) point out that this is really only significant where the diversity of protein intake is limited or in animal nutrition. Jansen (1979) reported that plant protein improves growth in children and adults regardless of whether lysine or methionine is the limiting amino acid.

Cytoplasmic proteins are synthesized first during the development of the kernel. CP are made up of albumins and globulins and are located in the aluerone layer. These proteins are globular in form with low molecular weight and are soluble in water and salt solutions. Once the CP are finished, the nitrogen is diverted to making storage proteins. Storage proteins are located in the endosperm and are made up of hordein and glutelin

proteins, which are soluble in alcohol and alkaline solutions, respectively, and have both high and low molecular weight proteins. The SP are high in glutamic acid, which is highly digestible. On the other hand, SP are low in lysine, arginine, threonine, and tryptophan (Lasztity, 1984). Therefore, it is easy to distinguish that the CP and SP are chemically, structurally, and physically different proteins. The majority of barley proteins are hordeins and glutelins. These two proteins account for over 70% of the total proteins in barley and are concentrated mainly in the endosperm. The albumins and globulins are present in the aleurone layer and germ and account for 20-30% of total proteins. Table 2.3 lists cereal and oilseeds with their protein fractions. Total protein in barley and oat is slightly higher than that of wheat, while soy is the highest at 38. Barley proteins are 23% glutelins compared to oat, which is 5%. Oat has 78% salt-soluble globulins, which is the primary reason for better protein nutritive value (Lockhart and Hurt, 1986). Soy protein composition is remarkably different and has 90% globulins and only 10% water soluble albumins.

Table 2.3 Protein content and composition of cereals and oilseeds[1]

	Total Protein	Albumin	Globulins	Prolamine	Glutelins
Barley	12	13	12	52	23
Oat	13	1	78	16	5
Soy	38	10	90	--	0
Wheat	12	3.5	10	69	16
Corn	9	4	2	55	39

[1]Protein content is given in g/100g of meal and protein classes in g/100g of protein (Adapted from Ross and MacRitchie (1995) and Lockhart and Hurt (1986)).

Table 2.4 lists essential amino acid composition of cereals and oilseeds. The quality of cereal protein is relative to its make-up and the digestibility. The amino acid profile is important as it dictates the physical, chemical and nutritional quality. The amino acid composition of oats is fairly constant over a wide range of protein contents (Lockhart and Hurt, 1986).

Table 2.4 Essential amino acid profile of eggs, cereals, and oilseeds[1]

Amino acid	Egg	Barley	Oats	Wheat	Corn	Soy	FAO standard
Lysine	6.4	3.5	3.7	2.9	2.7	6.3	4.2
Histidine	2.4	2.1	2.1	2.3	2.7	--	1.4
Arginie	6.6	4.7	6.3	46	4.2	--	5.0
Theronine	5.0	3.3	3.3	2.9	3.6	4.2	2.8
Valine	7.4	5.0	5.1	4.4	4.8	4.9	4.2
Methionine	3.1	1.7	1.7	1.5	1.9	1.4	2.2
Isoluecine	6.6	3.6	3.8	3.3	3.7	4.8	4.2
Leucine	8.8	6.7	7.3	6.7	12.5	7.8	4.8
Phenylalanine	5.8	5.1	5.0	4.5	4.9	5.2	2.8
Tryptophan	1.6	1.5	1.3	1.1	0.7	1.5	1.4

[1] Data from FAO (1970). Data given as g/100 g of protein.

2.4. Functional Properties

The food industry has changed from a commodity handling industry into a consumer driven market that produces food products compatible with a busy, yet healthy lifestyle (Kinsella and others, 1994). Food products must balance convenience with balanced nutrients, wholesomeness, and safety, in addition to offering quality attributes such as flavour, odour, colour, taste, texture, and mouthfeel (Kinsella and Phillips, 1988).

There is a fine balance between how processing can alter functional properties to meet consumer demands in the market place.

Functional properties of proteins relate to any physicochemical property, which affects the processing and/or behavior of the protein in a food system (Kinsellla, 1982). Functional ingredients such as proteins can provide functionality that may improve quality attributes of food plus most nutritional requirements. Table 2.5 states general properties of functional proteins with specific functional terms.

Table 2.5 Functional properties of proteins in foods[1]

General property	Functional criteria
Organoleptic	Colour, flavour, odor
Kinaesthetic	Mouthfeel, texture, smoothness, grittiness
Hydration	Solubility, wettability, swelling, thickening, gelling, synersis, viscosity, gelation
Surface	Emulsification, foaming
Structural/Rheological/Textural	Elasticity, cohesiveness, chewiness, adhesiveness, dough formation, texturizability, gelation, extrudability, grittiness

[1] Adapted from Kinsella, (1976).

Functional properties of proteins are determined by the protein structure (primary to tertiary), the charge (polar or neutral) as well as peptide bonding. Functional properties include emulsification, hydration and water binding, viscosity, foaming/whipping, and cohesion. Emulsification is dependent on the hydrophobic and hydrophilic balance (Zayas, 1977); this allows proteins to have the ability to disperse oil droplets in a continuous aqueous phase. An important example of emulsification is that of low-fat salad dressings. Dough formation relies on hydration and water binding ability of

proteins. Viscosity is critical for beverages and cohesion is important for textured products. Foaming and whipping are functional properties used in systems such as whipped cream, ice cream and other whipped desserts.

2.5. Functional Foods

Health Canada (1998) defines a "functional food" as a "product that is similar in appearance to or may be a conventional food, is consumed as part of a usual diet, but has demonstrated physiological benefits and/or reduces the risk of chronic disease beyond basic nutritional function". Whereas, a "nutraceutical" is a "product isolated or purified from foods and generally sold in medicinal forms not usually associated with food and demonstrated to have a physiological benefit or provide protection against chronic disease" (Health Canada, 1998). Examples of functional foods available on the retail market include yogurt with *Bifidus* cultures and orange juice with added calcium. Barley beta-glucan has been used in an orange flavoured beverage and a low-fat breakfast sausage (Bansema, 2000; Morin, 2001), which are considered functional foods. A cookie fortified with barley protein concentrate would also fit this category.

2.5.1. Market trends

Socio-economic changes in developed countries plus diet related health issues have driven the functional food market (Alldrick and others, 2002). Through ethical marketing, health claims and nutrition facts consumers can make informed choices about food consumption and take responsibility for individual health concerns.

Health, convenience, and private label product development were the top three drivers of the global food industry in 2004 (Sloan, 2005). Developed markets in particular saw an increase in high-protein/low-carb products. The low-carb diet trend affected the snack category to the tune of a 5% decline for all cookies and ice cream and 2% for cold cereals (Sloan, 2005). Even though Mintel (2004) predicts cookie sales will fall by 24% by 2009, the market for indulgent and premium products such as Elsa's Story Designers Collection of Brown Sugared Butter Cookies or Moravian's Cranberry Orange and Black Walnut Cookies are on the increase (Sloan, 2005). The development of higher quality treats in smaller, but satisfying portions are on the rise.

Ready-to-eat (RTE) segments sales have seen a 12% compounded annual growth rate since 1998 (Sloan, 2005). Some of the top category gains include salad kits (11%), nutrition/breakfast bars (32%), bowl dinners with meat (36%), and shelf stable dinners with meat (46%) (Sloan, 2005). Among the top consumer demands are portable convenience foods with eating utensils, that possess minimal preparation time requiring minimal cooking skills and/or equipment. Even though consumers are demanding convenience they still want "homemade taste in five minutes" and "fresh" is the most desirable food labeling claim (Sloan, 2005). Some of these consumer trends have been met within the bakery industry with products such as precut, fresh dough biscuits on disposable baking trays to bake at home in 8 min. The RTE segment will continue to grow as 8 out of 10 people prepare an evening meal at home with RTE products, coupled with the fact that consumers view cooking as one of their least favorite activities (Sloan, 2005). According to the Packaged Facts' 2004 U.S. Snack Market report, healthy snack

demand is the highest in the age category 18-24, who are demanding the nutritional snacks and energy/diet snack and bars. NPD food world reports that nutrition bars are the teens fastest-growing snack food, which is a change from traditional snack foods such as chocolate, candy, salty snacks, or cookies (Sloan, 2004). With the low-carb trend "promising to stick around" increasing sales in high protein, diet/low sugar category foods are expected. Within this category baking mixes, energy bars, breads and baked goods all had an increase in sales ranging from 19-34% in 2003 (Sloan, 2004).

Trends in the U.S. influence Canadian trends; however, the data are not as abundant. Looking at consumption trends from Statistics Canada; consumption of grain products accounts for 1/3 of the energy intake; with bread being the greatest energy source from grains at 8% of total energy, while breakfast cereals, pasta, and rice each contribute around 3% of total energy (AGNAP, 1996). Nearly 40% of the carbohydrate intake is from grain products, which contributes only 2% of fat intake, while bakery products account for 11% of the fat intake. Protein from grains amounts to approximately 1/5 of the Canadians protein intake (AGNAP, 1996). Figure 2.4 illustrates the percentage of bakery and cereal products in the average Canadian diet for the year 1999 (NIN, 1999).

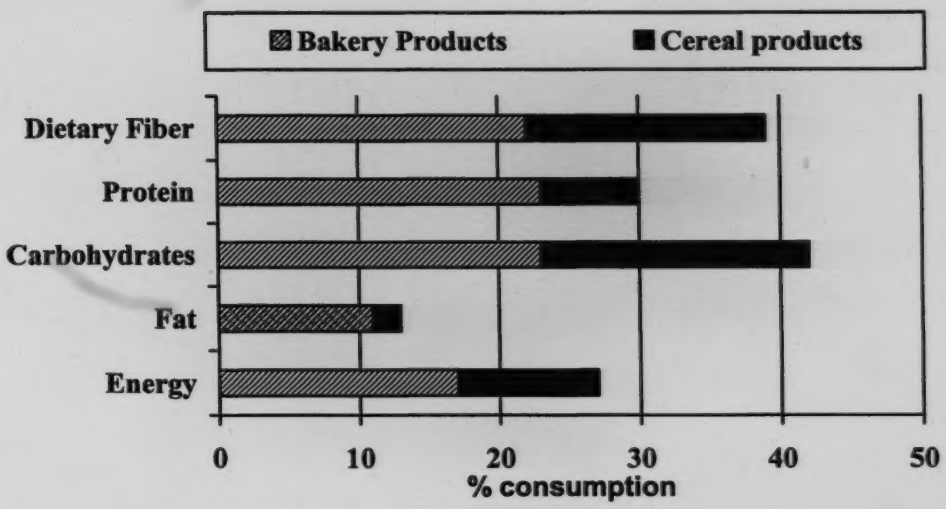

Figure 2.4 Nutritional contributions of grain products to the average Canadian diet (adapted from NIN, 1999).

Table 2.6 compares consumer grain product choices from 1990 to 1996. A steady for overall bakery products between 1990 to 1996 with a small increase in unsweetened rolls an buns with a corresponding small decrease in other category, which include cracker, cookies, sweet biscuits, doughnuts, and pies/pastries. A large increase in cereal products for the same time frame specifically the categories of pasta, rice, and other category, which includes flour-based mixes, cereal based snack foods and a decline in flour choices (Stats Canada, 1996). Given this data are from 1996, they do not truly reflect how many Canadians are following the high protein, low-carb trend. However, this data show an increase in cereal based snack foods, which is reflective of various types of cereal bars such as granola bars as part of fast paced on the go eating lifestyles. The average weekly food expenditure/household in Canada for bakery and other cereal products in 1996 was $12.47 compared to Alberta at $12.02 and for the city of Edmonton

it was lower at $11.63 (Stats Canada, 1996). The category includes bread, cookies, cakes, pasta products and breakfast cereals. Functional foods and their health benefits will have an impact on grain products in the Canadian diet (NIN, 1999). The shift towards whole grain breads and low-fat baked goods could be important for food scientists and health of the nation.

Table 2.6 Trends in Canadian consumer grain product choices[1]

Product Category	1990	1996
Bakery products	**113.4**	**113.6**
Bread	62.7	63.0
Unsweetened rolls and buns	15.3	17.0
Other[2]	35.6	33.4
Cereal Products	**69.9**	**79.6**
Pasta products	14.5	20.0
Rice	13.2	18.6
Flour	20.3	16.4
Breakfast cereal	14.2	15.3
Other[3]	7.7	9.3

[1] estimated consumption: g/ca/d adapted from NIN (1999).
[2]crackers, cookies, sweet biscuits, doughnuts, dessert pies, pastries.
[3]other grains (milled or unmilled) flour-based mixes, cereal based snack foods.

Data from food consumption statistics (Stats Canada, 2002) indicate that the consumption of protein has been on the rise since the mid 1990's, and the main source of protein is beef. However, cereals do represent an important source of protein and contributed 23% of the total protein consumed by Canadians in 2001. Market trends and consumer demands will fluctuate as consumers continue to take a proactive role in

preventing the onset of chronic diseases through diet. The high-protein, low-carbohydrate trend continues reducing traditional sweet-goods and grain-based foods sales by $10 billion as two-thirds of Americans' lifestyles reflect a low-carb intake (Hartman, 2003). Nutritionists and food scientists along with the food industry need to work together in providing functional foods to meet consumer demands and to convey scientific evidence on the efficacy of such products.

2.5.2. Health claims

In developed nations, food has moved from satisfying basic survival to enhancing and optimizing health, hence the term "functional foods". Informing consumers of such properties and benefits along with protecting consumers must be done with scientific data supporting such claims and regulations to provide structure and reliability through government policies and agencies. Currently, in the U.S. health claims describe the relationship between a food, food component, or dietary supplement ingredient, reducing the risk of a disease or health-related condition. The Nutrition Labeling and Education Act (NLEA) authorized the Food and Drug Administration (FDA) to allow certain disease-risk-reduction claims on food labeling known as health claims (Clydesdale, 2004). According to the NLEA, a health claim specifically characterizes the relationship between a nutrient and a disease or medical condition that is related to diet. There are two main types of claims that may apply to functional foods including health claims and structure/function claims. In the U.S., health claims involve several regulatory bodies including the FDA, and the Consumer Health Information for Better Nutrition Initiative

of 2003. The Institute of Food Technologists (IFT) expert panel on functional foods is recommending that scientific evidence be accurately relayed through labeling and health claims in order for consumers to act on the information for the benefit of public health (Clydesdale, 2004). Currently, there are 12 approved health claims in the U.S. the following 4 authorized health claims are of interest for this research as they deal with cereal grains and soy protein.

1. Fiber-containing grain products, fruit and vegetables and cancer. "Diets low in fat and rich in fiber-containing grain products, fruits and vegetables may reduce the risk of some types of cancer, a disease associated with many factors". Typical types of foods include whole-grain breads and cereals, fruits, and vegetables.

2. Fruits, vegetables and grain products that contain fiber, particularly soluble fiber, and risk of coronary heart disease. "Diets low in saturated fat and cholesterol and rich in fruits, vegetables, and grain products that contain some types of dietary fiber, particularly soluble fiber, may reduce the risk of heart disease, a disease associated with many factors". Typical types of foods include: fruits, vegetables, and whole-grain bread and cereals.

3. Dietary soluble fibre, such as that found in whole oats and the risk of coronary heart disease. When included in a diet low in saturated fat and cholesterol, soluble fibre may affect blood lipid levels, such as cholesterol, and thus lower the risk of heart disease. A sample health claim could be "diets low in saturated fat and cholesterol that include 3 g of soluble fibre from whole oats per day may reduce the risk of heart disease. One serving of the whole-oats product provides – grams

of this soluble fibre." To quality for this claim a product must contain at least 0,75 g of beta-glucan per serving. Typical foods include oatmeal cookies, muffins, hot or cold cereals and breads made with rolled oats, oat bran or whole oat flour.

4. Soy protein and risk of coronary heart disease. A sample health claim could be "diets low in saturated fat and cholesterol that include 25 g of soy protein a day may reduce the risk of heart disease. One serving of (name food) supplies _ g of soy protein." To qualify for this health claim foods must contain: at least 6.25 g of soy protein per serving; low in fat (less than 3 g); low in saturated fat (less than 1 g); low in cholesterol (less than 20 mg), and have sodium values of less than 480 mg for individual foods. Typical foods include soy meat products, soy beverages, soy yogurt, soy cheese, soy roasted nuts or soy protein bars.

Of particular interest for this thesis are those health claims dealing with oat and soy along with the anticipated claim for barley. In 2004, the National Food Barley Council in the U.S. petitioned the FDA for a health claim for barley soluble fibre and heart disease for products including barley either whole or pearled, barley flour, and barley flakes. An outcome is expected in late 2005.

Quaker Oats was the company to file the original health claim for oats in 1997, which was approved for rolled oats, oat flour and oat bran. In 2002, an amendment was made to the claim to include concentrates of beta-glucan of up to 10% specifically Oatrim®. This amendment reflects changes in processing that allows for beta-glucan concentrates to be developed as well as increasing scientific evidence to support these

health claims. Since then the Quaker Oat Company has spent upwards of $70 million in advertising for heart healthy oat products.

Twenty seven clinical studies determined that diets, which contained four daily servings of soy can reduce low density lipoproteins by as much as 10% (Henkel, 2000). Grocery Manufacturers of America reports an increase in sales for various soy food products after the FDA approved health claim. With the approval of the soy protein health claims it is estimated that soy products would increase in sales to $6 billion up from only $1 billion in 1997 prior to the health claim. In 1999, over 300 new soy products were placed on the U.S. market up from 170 products in 1998 (Harland, 2002).

The American Dietetic Association (ADA) survey showed women were more likely to be aware of possible health benefits compared to men for health related effects of 10 specific foods or nutrients. The largest response was for low-fat foods and half of the respondents reported being familiar with soy-based foods. Interestingly, only 23% reported increased consumption of soy-based foods meaning that familiarity does not translate into consumption; therefore, some barriers still exist with soy-based foods. The ADA survey indicated that television is the primary source of nutrition information with magazines and newspapers as secondary sources (ADA, 2002). These results suggest that media can then be used to effectively disseminate nutrition information to increase public awareness of such health benefits.

A survey conducted by Food Marketing Inst. (FMI, 2004) reports on shoppers who purchase products based on a specified health-related claim. The percentage of the population that indicated health claims influenced their purchase is indicated in Table 2.7,

which identify over 50% of the population surveyed, made a purchase because of a health benefit and because of a health claim on the food package. The survey included various age groups from gen Y to matures. The matures group reported the largest purchases were made because of a "low-fat claim"; whereas, gen Y reported 59% and 55% made purchases for the claims of "high Vitamin C" and "high in calcium", respectively. "Reducing the risk of cancer" health claim ranked lowest for all age categories (<50%). There was a trend showing that with increasing age the most popular health claim was for "reduces the risk of heat disease" (Sloan, 2005).

Structure/function claims are different from health claims as they do not claim to reduce the risk of certain diseases, but rather describe the dietary impact of the substance on the structure or function of the body. An example of a typical structure/function claim would be "protein helps to build strong muscles".

The regulatory situation in Canada has been somewhat different compared to the U.S. given the fact that no specific health claims have been allowed until January, 2005. Diet related structure-function claims have been long standing and provide the only connection Canadian consumers could make between food products and health. These diet related structure-function claims include:

1. Sodium and potassium, and the link to high blood pressure
2. Calcium and vitamin D, and the link to osteoporosis
3. Saturated fat, *trans* fat, and the link to heart disease
4. Vegetables and fruit, and the link to some types of cancer

5. Chewing gum, hard candy, breath-freshening products and the reduced risk of tooth decay with minimal amounts of carbohydrates that promote tooth decay.

Table 2.7 Food shoppers who purchased a product based on health claim on food package[1]

		Percent by generation				% saying health concerns influence purchase	
Claim	**Total%**	**Gen Y**	**Gen X**	**Boomers**	**Matures**	**Yes**	**No**
Low fat	63	52	61	64	66	72	54
Whole grain	62	49	55	68	61	67	56
Low in saturated fat	55	44	49	55	60	64	45
Low calorie	52	42	52	54	52	60	45
High Calcium	51	58	55	47	48	55	46
High Vit.C	51	57	59	49	46	53	48
Low Sodium	48	31	46	47	56	58	38
Vitamin enriched	47	51	52	47	41	53	40
Sugar Free	46	33	46	46	49	56	35
Reduces risk of heart disease	42	31	52	43	49	54	30
Low carb	40	41	39	43	36	47	33
Reduces risk of cancer	26	19	19	24	35	32	19

[1]Adapted from Sloan (2005).

Functional food products are only important if the consumer understands what the benefits are in consuming such products and one way to inform the consumer is through labeling. New regulations in Canada require most food labels to carry a mandatory Nutrition Facts table as a result of the labeling requirements that came into effect in January 1, 2003 (CFIA, 2003). Food manufacturers will have to declare the number of calories, the amount of fat including saturated and *trans* fats along with cholesterol, sodium, carbohydrate, fibre, sugars, protein, vitamins A, and C, calcium and iron. The then Minister of Health Anne McLellan said, "nutrition information is essential to helping Canadians make informed choices for healthy living" and that "the Nutrition Facts table will allow Canadians to compare products more easily, assess the nutritional value of more foods and better manage special diets" (Health Canada, 2005). For the first time in Canada nutrient content claims and diet related health claim pertaining to reducing the risk of heart disease, cancer, osteoporosis and high blood pressure are allowed (Health Canada 2003). The direct health care costs of a poor diet are estimated to be $1.8 billion whereas the economic burden extends to over $6 billion annually (Health Canada, 2003). Health Canada estimates that nutrition labels could save $5.3 billion in direct and indirect costs over the next 20 years. This estimate includes economic costs associated with loss of productivity along with treating diseases such as cancer, diabetes, and coronary heart disease. Cardiovascular disease costs about $7 million in direct costs annually and around $17 million in indirect costs (Heart and Stroke Foundation, 2003). Nutrition labeling therefore is a practical tool to assist Canadians to make informed

choices for healthy eating and in turn to reduce demands and related costs to the health care system.

New regulations for nutrient content and diet related health claims specify what health claims are allowed based on recognized health and scientific data. Nutrient content labeling allows products fortified with protein at levels of 5 – 9 g/serving to state "good source of protein" on the label, whereas an "excellent source of protein" on the label means products containing ≥10 g/serving and a "source of protein" is <5 g/serving (Canadian Food Labeling Regulations, 1996). Other nutrient claims are for reduced levels of saturated fat that include restriction on levels of both saturated and *trans* fatty acids. The nutrient content claim "light" can be used for reduced fat or reduced calories, but it can also be used as a sensory characteristic such as light in colour.

2.6. Bakery Products

Due to the major health concerns such as obesity and diabetes, food processors are addressing these health issues with a wide array of products like low-fat, low-calorie and zero-carb products. Fortification of bakery products with vitamins and minerals plus functional ingredients is driving product development to create a balance between nutrition and satisfactory sensory attributes. According to Leatherhead Food International, the bakery market will reach 36 million tonnes by 2007 with specialty breads and products enriched with fibre and functional ingredients (Ahmed, 2004).

Soy protein is already incorporated into a wide array of food products such as cereals, baked goods, cream soups, energy bars, beverages, meat and meat analogues.

Cereal bars have been developed with healthy nutrients and for convenience for on the go busy consumers; however, the snack food industry is facing scrutiny from media as well as from consumer groups who are citing *trans* fats from snack foods as a major contributor to increasing obesity and heart disease (Winkle and Poole, 2002). These are some of the driving forces behind the United Soybean Board and the Better Bean Initiative programs to develop soybean seed with enhanced composition traits to meet the requirements of oil and protein end users. Along with developing a soybean with reduced saturated fats, a reduction in linolenic acid in order to enhance flavour and oxidative stability is an initiative within the industry that was set up to find new product development opportunities for enhanced soybeans (Poole, 2002).

Soy proteins can improve texture, and moisture, and fat retention in bakery products. Isolates can be used as egg or milk replacers due to their high water binding capacity. The hydrophilic nature of soy proteins may increase batter viscosity, which in turn may improve moistness of baked products. The use of other plant proteins such as barley has not been investigated as thoroughly as soy. However, with the development of fractionation processes to obtain specific components from barley such as beta-glucan, lipids, starch, and proteins there is a potential market to develop food products with these functional ingredients in bakery products.

2.6.1. Low-fat and low-carb products

The National Health and Nutrition Examination Survey from 2004 indicated Americans are consuming 34% of calories as fat in their diet (CDC, 2002). This figure is

lower than in previous years; however, the current rate still falls short of the recommendation of 30% or less of total caloric intake. In conjunction with the nutrition recommendations to decrease fat intake from 40% to 30% there has been an increasing demand from consumers for low-fat products. The number of fat reduced or fat modified products increased in the American market over an eight year span (1990-98) in which 15,697 fat modified products were introduced (Katz, 1998). There was only a marginal increase from 73% to 75% from 1995 to 1997 (Sigman-Grant, 1997) in the consumption of low fat products indicating that low fat products are a stable part of the American diet. The 2004 National consumer survey from the Calorie Control Council reports that 40% of American adults are consuming reduced-fat chips/snack foods, while 33% or 71 million people are currently on some type of diet (CCC, 2004).

Cookies are traditionally high fat food products that acquire texture and flavour characteristics from fat (Malovany, 1995; Romanchik-Cerpovicz, 2002). Consequently, cookies have been the target of low-fat reformulations with various ingredient substitutions. Fat typically provides cookies with flavour, texture, and moisture; therefore, reducing fat will affect each of these attributes as well as aroma and appearance and thus replacement of fat is a complex issue. Fat substitutes are carbohydrate-, protein- or lipid-based materials with each material possessing particular properties to mimic fat characteristics in the baking process. The high fat content of cookies yields tenderness in soft dough cookies. The fat replacer then must be able to maintain adequate or superior characteristics of the full fat recipes. In most instances, only a portion of the fat can be replaced and the product would still maintain acceptable

properties. For example, Oatrim®, soluble beta-glucan and amylodextrins from oat flour was used successfully at 50% substitution level (Inglett and others, 1994; Warner and Inglett, 1997). Zoulia and others (2000) found that 50% substitution with Lites and Simplesse® dry 100 was comparable to the control for flavour and general acceptance, but produced a harder cookie. Prune puree, a fruit-based fat substitute, was successfully added to oatmeal and chocolate chip cookies (Swanson and Munsayac, 1999). Consumption of sugar-free cakes, cookies or other baked goods has increased from 20% to 29% according to the Calorie Control Council (2000) in the U.S.

The low-carb craze is challenging the bakery industry with evolving perceptions and trends. Consumers following low-carb diets are prone to reducing their intake of wheat-based products. The low-carb dieting trend equates to a reduction in the consumption of bread, crackers, cakes, and biscuits all of which impacts the bakery industry. Thomson (2004) reports that studies in the U.S. show only 65% of the population consuming bread products for breakfast or that they are skipping breakfast, which is resulting in lower consumption of cereal products and that 45% of the consumers surveyed perceive bread as fattening. Overall, a reduction in the consumption of baked products equates that baked goods and food manufactures a like are looking at different ways to incorporate functional ingredients into baked products to match consumers demands and market trends. Some of the bakery products have been enriched with either fibre or protein.

2.6.2. Fibre-enriched products

Current nutrition recommendations for dietary fibre are 25 g/day, while the majority of the population is only consuming 16 g/day (CDC, 2002). Consequently, increasing dietary fibre through fortification of food products has been investigated by several researchers. Bakery products are useful vehicles for incorporating functional ingredients like fibre.

Barley flour and barley bran, as a source of dietary fiber, have been used to partially or completely replace wheat flour in baked goods (Swanson and Penfield, 1982; Chaundray and Weber, 1990; Newman and others, 1991; Berglund and others, 1992). All researchers noted different quality characteristics such as smaller volume, higher gumminess, increased tenderness, and poorer crumb structure as compared to products produced with wheat flour.

High fibre cookies were evaluated by Ozboy and Koksel (1997) who used wheat bran at 4-20% and reported that cookie quality was inversely affected with increasing levels of bran. Wheat bran could be added at a level of 2.5% without significantly affecting texture of cookies (Gujral and others, 2003).

2.6.3. Protein-enriched products

Enrichment of cereal-based foods with legumes has been investigated by various researchers (Tsen and others, 1973; Warren and others, 1983; Claughton and Pearce, 1989; Adeyemi and others, 1992; Akubor and others, 2000; Akubor, 2004). The protein source must be suitable for cookie formulations in that it should not negatively alter

functionality such as crispness or hardness, or cause undesirable changes in dough elasticity or consistency (Lorenz, 1983). The protein ingredient should not impart any off flavour; therefore, the requirement to be bland or mild flavour is essential. A high PER is vital given the consumption rate of such food products and that vegetable proteins as protein-enriching ingredients are playing an integral part of the food industry at present. Table 2.8 shows the PER of soy protein in comparison to other protein sources. Soy protein concentrate PER is lower than that of whey protein concentrate, but is similar to casein; however, casein is 97% protein compared to only 70% protein in soy concentrate.

Table 2.8 Protein ingredients for cookie formulations and corresponding PER values.[1]

Additive	PER[2]	% Protein
Soy protein concentrate	2.3	70
Soy protein isolate	1.8	90
Peanut isolate	1.8	78-92
Whey protein concentrate	3.2	80
Casein	2.5	97

[1]Modified from Lorenz (1983).
[2]PER= protein efficiency ratio.

Whey protein, a high quality protein, not only adds nutrition to bakery products, but it also improves sensory attributes of low-fat or zero-fat baked good such as muffins and cakes (Ahmed, 2004). Whey protein is readily available, economical, and provides a clean label, although there are some stability problems with flavour during prolonged storage (Burrington, 2004).

2.6.4. Cookies

Biscuits can be classified as products that are cereal based, baked to a moisture content of less than 5%, with fat and sugar being the main ingredients. The name 'biscuit' is used throughout the UK whereas the name 'cookie' is generally used in North America, but biscuits, cookies and crackers are grouped according to texture and hardness, method of forming the dough, and the enrichment of the recipe with fat and sugar (Manley, 1991). The main ingredients in cookies are flour, fat, and sugar. Cookie flour is normally long patent or straight grade flour with flour specifications dependent on formulation and desired cookie spread (Manley, 1991). Cookies often use soft wheat flours with low protein content and weaker gluten strength thus producing a cookie with larger diameter and tender bite (Hoseney and others 1988). Abboud and others (1985) reported soft wheat cookie dough yields greater spread with longer expansion time compared to poor quality hard wheat. The main difference among the different groups of biscuits is the structure of gluten that imparts extensibility along with cohesiveness to the dough. Wheat gluten is known for its ability to hold and form three dimensional structures. Gluten strength depends on the protein concentration, as well the protein composition. Gluten allows dough to be elastic, extensible and stable after mixing. Figure 2.5 is a graph depicting the relationship of sugar and fat enrichment in biscuit recipes and also indicates gluten structure.

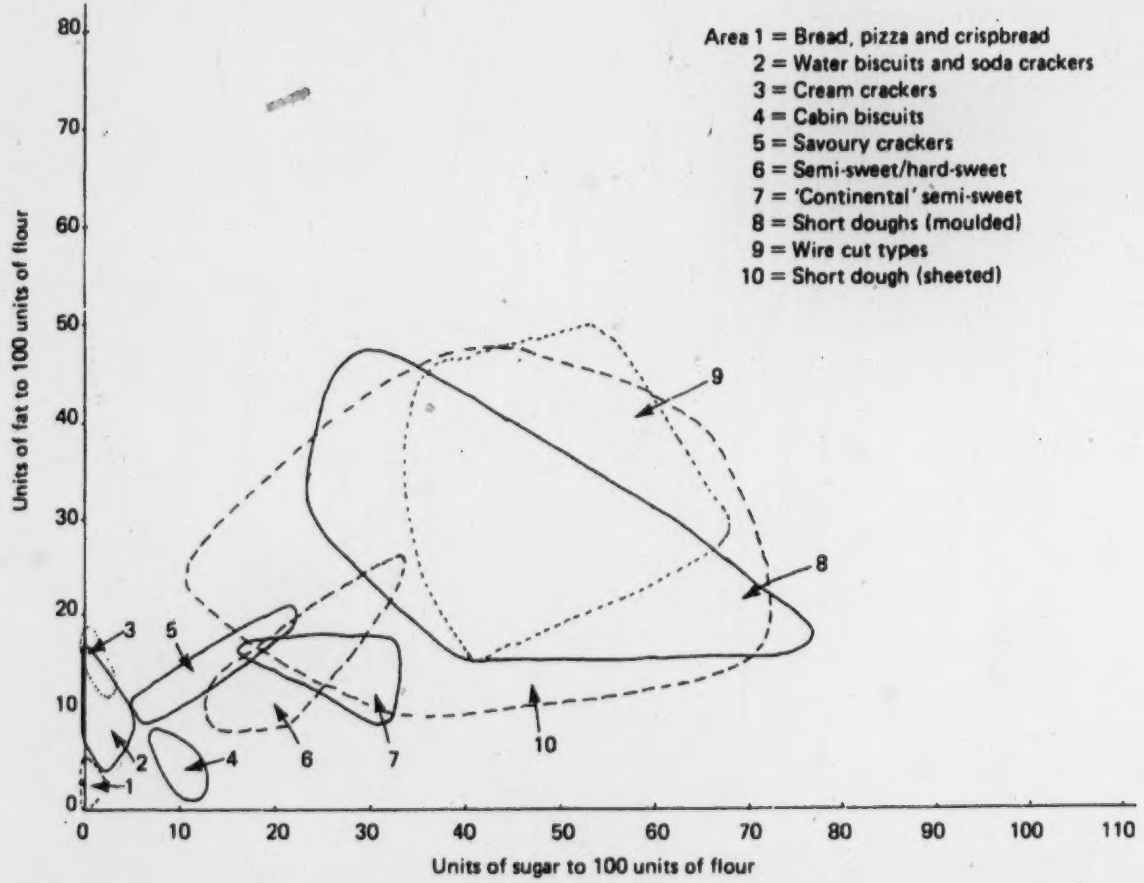

Figure 2.5 Relationship of sugar and fat in different types of biscuit recipes (Adapted from Manley, 1991).

In short doughs (area 8 in Figure 2.5) very little gluten is developed forming a non-cohesive structure; therefore, the dough does not shrink, but will increase in 'spread' during baking (Manley, 1991). Figure 2.5 also shows that the main difference between all biscuit groups is the cohesiveness of the dough, which is affected by both the sugar and fat contents. There is a certain amount of fat and a minimal amount of sugar required to meet acceptable texture. The fat acts as a tenderizer for the dough, while the sugar may have a softening effect on gluten.

Biscuits enriched with protein are often made with soy flour or caseinate. The main concern with using soy is the strong unpleasant flavour. When selecting a protein ingredient to enrich cookie formulations the protein should have a bland or pleasant flavour, low water absorption capacity and a high PER (Lorenz, 1983). Protein should not affect the texture or spread or impart undesirable changes to the dough consistency. Taste and functionality are paramount when selecting a protein substitute. Another major concern is that altering the starting materials affects the development of the dough. Dough consistency also depends upon the type of flour and other cereals used. Strong wheat flours with high dough elasticity may cause problems in cookie production (Hoseney, 1988).

Cookies are often consumed for pleasure as snack food or to complement other foods. Cookies are generally not considered nutritious in light of the fact that consumption of high levels of fat is related to heart disease and high sucrose levels are considered to be detrimental to health through increased blood sugars and cause of dental caries. Cookies are however, ideal for carrying vitamins, minerals, fibre, or tailored to

specific groups or dietary needs. Because they are so widely accepted, they vary in form and taste; they are convenient with a long shelf life and appeal to a wide range of ages and health needs. Cookies can be an ideal mode for delivering functional ingredients and increase value-added products such as barley protein cookies. Protein fortified products are gaining in popularity as the high protein, low-carb movement continues in America (Sloan, 2004). Consumers are demanding food products to meet their nutritional health without giving up taste. Biscuits can be tailored to suit various eating episodes from breakfast to sporting sessions with a combination of nutrition, energy, health, and satisfying taste. There were more than 100 biscuits on the market between January, 2003 and February, 2004 with health or nutritional claims (Roquette, 2004). The four main nutritional claims made for biscuits included: sugar or fat content, enrichments with minerals and vitamins, improvement of fibre and energy availability (Roquette, 2004). The most common claim at 60% was related to sugar or fat content.

The cookie and cracker market have seen several changes throughout the years and have been required to adapt to consumer trends. During the 80's the trend was low fat formulations, during the 90's it was high fibre and now in the 21st century the predominant trend is low-carb and high-protein trends plus reduction in *trans* fats.

Cookies in the U.S. market accounted for $588 million, which equates to 6% of in-store bakery sales and $531 million or 9% of retail sales for the year ending 2004 (Anon, 1995). Cookies and crackers are the second most popular category of bakery foods with chocolate chip cookies exhibiting the highest rate of consumption (Anon, 1982).

According to 2001 Food Market Institute studies, 78% of supermarket shoppers use fortified food to maintain their health (Tockman, 2002). With increasing awareness of nutrition and its role in preventing chronic diseases such as hypertension, diabetes and cardiovascular diseases healthy eating is steadily on the rise. Protein fortification of snack foods such as cookies address the consumer trends of high protein diets and the consumer's perceived needs of "healthy" foods.

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3. PHYSICAL AND SENSORY CHARACTERISTICS OF SUGAR COOKIES FORMULATED WITH CONCENTRATED BARLEY PROTEIN[1]

3.1. Introduction

Bakery products are widely consumed in the North American diet. In Canada, consumption of grain-based products in 2002 was up to 65.6 kg/person and wheat flour accounted for 82% of all cereal products consumed (Stats Canada, 2002). The most common sources of protein in baked goods are eggs, milk, or whey protein. Wheat flour has a protein content that varies from 6 to 18%; however, it is often low in essential amino acids such as lysine (Warrnen and others, 1983). Cookies are popular and a common snack food because of their convenience, long shelf life and acceptability. Most cookies are low in protein because the main ingredient is soft wheat flour. On the other hand, with the growing interest in low-carbohydrate foods there is an increasing market demand for protein fortified foods such as cookies.

Various researchers have studied development cookie formulas with fat replacer or fibre enrichment including the addition of prune puree (Perry and others, 2003) and orange pulp (Larrea, 2004); however, only a few studies have evaluated protein enrichment. Enrichment of bakery products with oilseed proteins such as soy has been wide spread (Tsen and Tang, 1971; Onayemi and Lorenz, 1978; Klein and others 1995; Chen and others, 2003), yet cereal based protein sources have not been investigated.

[1] A version of this chapter is to be submitted to The Journal of Food Science for consideration for publication.

Lorenz (1983) completed an in-depth evaluation of protein fortification of crackers and chocolate chip cookies using fababean protein concentrate. Warren and others (1983) reported on various sources of protein in cookies, crackers, and snack bars. Sesame seed flour was used to significantly increase protein content of biscuits (Alobo, 2000). Giami and Barber (2004) used protein concentrates of un-germinated and germinated fluted pumpkin seeds in cookie formulations that were nutritionally comparable to control cookies, but at the expense of acceptability.

A tool that can be used to assess food product quality during formulation development is Principle Components Analysis (PCA). PCA reduces the number of original variables (dependent) into principle components (PC) in which a few number of variables are generated that are linear combinations of the original data set. Therefore, the main intent of PCA is to explain as much of the variation in the original data in a few principle components. PCA is a valuable tool to relate consumer acceptability data to data from descriptive sensory evaluations with the intent to describe characteristics of the product that drive consumer preference (McEwan and others, 1998). For example, Naes and Nyvold (2003) used PCA as an efficient tool for food quality measurements, such as sensory analysis and consumer testing. PCA is applied directly to attributes and then prototypes are developed according to output plots. Martinez and others (2002) used PCA to show sensory descriptors of crackers that drove the preference of some of the consumer clusters. These researchers were interested in finding the relationship between acceptability of consumers and the descriptive data from a trained sensory panel for a cracker. Quilez and others (2005) plotted two principal factors using discriminate

analysis and found perfect separation of the croissant group from the muffin group. There was also perfect separation between the fresh baked and frozen group in both of these baked product categories. They also reported that there was no adverse effect on taste or appearance with the inclusion of functional ingredients such as phytosterol esters in either of these bakery products. Chabanet (2000) used PCA to determine flavour and taste differences among 10 varieties of potatoes. Murray and others (2002) used PCA to establish interactions between eight bread samples and their associated sensory characteristics and developed a sensory lexicon for commercially available breads. These studies demonstrate that PCA is a valuable tool to study relationships between trained sensory panel results, consumer acceptability and instrumental measures. However, such an approach has not been applied to cookies.

With recent process developments in fractionation of barley for valuable components such as beta-glucan, the protein fraction is anticipated to become an important source of cereal protein. Barley is a cereal crop grown in Western Canada and in particular Alberta that has several agronomic advantages, but is currently limited in human food uses. The need to develop products that contribute to a healthy diet continues to grow as consumers demand new products. Cereal-based products modified with dietary fibre or reduced fat have been a key area of growth while cereal protein sources have received minimal emphasis. Development of nutritionally enhanced baked products such as cookies with protein has been limited. Furthermore, how the additional protein affects functionality of dough and taste attributes requires investigation. Lorenz (1983) studied protein fortification of cookies, but did not address sensory evaluation aspects.

Increasing the content of a desirable component such as protein will affect the process along with the appearance of the final product as reported by Pomeranz (1977) for bread that was enhanced with dietary fibre where it led to changes in dough rheology as well as bread texture and appearance.

Therefore, the overall objective of this study was to investigate the effect of incorporation of concentrated barley protein at different levels (0-45% flour substitution) on physical and sensory characteristics of sugar-type cookie. The specific objectives were:

1. to determine chemical composition of concentrated barley protein and the cookie formulations,
2. to compare the physical characteristics of a standard sugar cookie to those made with concentrated barley protein using instrumental techniques,
3. to determine sensory attributes of cookies enriched with concentrated barley protein using quantitative descriptive analysis
4. to determine consumer overall opinion of cookies enriched with concentrated barley protein, and
5. to correlate sensory evaluation results obtained from trained and consumer panels using Principle Components Analysis.

3.2. Materials and Methods

3.2.1. Materials

CDC Candle, a hull-less waxy type barley variety was provided by Agricore United (Calgary, AB) and was used as the starting material in this study. Barley grains were cleaned and pearled to 19% at the Center for Agri-Industrial Technology (Edmonton, AB). The 19% pearled grain was then milled into flour using a hammer mill fitted with a 0.5 mm screen prior to extraction. Both milling and extraction processes were conducted at the Food Processing Development Centre (Leduc, AB) prior to this study. Protein concentrate was obtained by alkaline extraction (Lekhi, 2004) using sodium hydroxide (NaOH) with pH adjustment to 10 at ambient temperature (23°C) followed by isoelectric precipitation and spray drying of protein fraction.

All baking materials were purchased locally at retail grocers in Edmonton, AB as follows: all purpose flour (Canada Safeway, Calgary, AB), Roger's white granulated sugar (Vancouver, B.C.), Crisco shortening (J.M. Smucker, Toronto, ON), Canola Harvest margarine (Canbra Foods Ltd., Lethbridge, AB), eggs grade A Lucerne medium (Canada Safeway, Calgary, AB), vanilla flavouring Club House (McCormick, London, ON), Sifto iodized table salt (Mississaugau, ON), and baking soda (Canada Safeway, Calgary, AB).

3.2.2. Proximate analysis

Proximate analyses were conducted on concentrated barley protein and on all 9

cookie treatments (0-45%). Moisture and ash contents were determined using AACC methods 44-19 and 08-01, respectively (AACC, 1981). Lipid content was determined according to AOAC method 24.005 (AOAC, 1999). Protein content (%N x 6.25) was determined using a nitrogen analyzer (Model FP 428, Leoc Corp., St. Joseph, MI). Beta-glucan and starch determinations were done according to McCleary and Glennie-Holmes (1985) and McCleary and others (1994), respectively, using Megazyme assay kits (Megazyme, Inc. Wicklow, Ireland). All analyses of concentrated barley protein and cookies were carried out in duplicate.

3.2.3. Preparation of cookies

Concentrated barley protein was used at 0, 15, 20, 25, 30, 35, 35.7, 40, and 45% (w/w) substitution for all purpose flour (Molt, 2001). The cookie formulation presented in Table 3.1 shows straight percentage replacement of all purpose flour with concentrated barley protein. All cookie ingredients were weighed on a two digit electronic balance (Denver Instrument, Arvada, CO) and cookies were mixed using a Kitchen Aid electric mixer (model K45SS, Troy, OH). Cookie preparation incorporated the creaming method as illustrated in Figure 3.1. The fats were first mixed on high speed for 30 s, the sugar was added 1/3 at a time and mixed for 30 s after each addition. Before each addition of ingredients, the mixture was scraped down. Eggs and vanilla were premixed with a fork and added after the sugar followed by mixing for 1 min on high speed. The flour, protein concentrate, baking soda, and salt were premixed with a fork and then added ¼ at a time into the wet mixture with mixing for 1 min on medium speed. A cookie press (Kuhn

Rikon, Switzerland) was used to produce uniform cookies and baking was carried out in a Baker's Pride convection oven (model X3000, Bakers' Pride Canada, Inc., Lachine, QB).

Table 3.1 Cookie formulations for the 9 treatments of 0-45% (w/w) flour substitution with concentrated barley protein

	0%	15%	20%	25%	30%	35%	37.5%	40%	45%
Protein (g)	0	43	45.5	56.75	68.1	79.5	85.1	90.8	102
Flour (g)	227	193	181.6	170.25	158.9	147.5	141.9	136.2	125
Margarine (g)	114	114	114	114	114	114	114	114	114
Shortening (g)	100	100	100	100	100	100	100	100	100
Sugar (g)	152	152	152	152	152	152	152	152	152
Salt (g)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Baking soda (g)	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Vanilla (g)	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
Egg	2	2	2	2	2	2	2	2	2

3.2.4. Instrumental analysis

3.2.4.1. Cookie spread

Cookie spread was determined according to AACC method 10-50D was followed (AACC, 1997). The control followed the standard method while the test cookies had replacement of all purpose flour with 15%, 25%, and 45% (w/w) concentrated barley protein. Modifications made to the method include reduction of baking time from 10 min to 8 min at 200^0C. Wooden gauges (6 mm) and a cookie cutter (62 mm) were used to cut cookies for cookie spread testing. Cookie thickness was determined by taking six cookies

Crisco
Canola Harvest Margarine
Eggs
Flour
Mix 30 s on high speed
Add vanilla
Add Protein
Mix with a fork
Add sugar 1/3 at a time, Mix for 30 s after each addition
Beat with a fork
Add Salt and Baking soda
Mix on high 1 min
Mix with a fork
(1/4 at a time)
Mix 1 min after each addition
Let dough rest for 10 min
Fill cookie press
Place 4 across and 5 down on each cookie sheet
Bake at 200 °C for 8 min.
Cool on cookie sheet

Figure 3.1 Flow diagram of cookie production

stacked on top of each other and measuring with fiberglass non-stretching measuring tape. The same six cookies were then stacked upon each other in a different order and then re-measured. The averages for the 2 measurements were reported. The width of the cookies was derived by taking the same six cookies, placing them side by side and measuring from end to end, rearranging the order and then re-measuring. The average value was reported for the 2 separate measurements. The cookie spread value is a ratio of width divided by height. All samples were evaluated in duplicate for each of two replications.

3.2.4.2. Compression testing

3.2.4.2.1. Cookie Dough

Compression force was evaluated on raw cookie dough prepared according to cookie spread procedure. A standard cylindrical shape with a diameter of 42 mm and thickness of 20 mm was cut in duplicate from each batch of cookie spread dough. Cookie dough from each treatment (0%, 15%, 25%, 45%) was compressed using an Instron Universal Testing Machine (Model 3201, Instron Corp., Canton, MA) longitudinally to 50% of its original height with a 5 kg load cell at a crosshead speed of 100 mm/min. Compression force (kgF) was recorded as a function of displacement (mm) and maximum force was then taken as a measure of dough strength. Data were processed with Instron series IX software (Instron Corp., Canton, MA). All analysis were preformed in duplicate for each of the two replications.

3.2.4.2.2. Whole cookie

Shear force was evaluated on whole baked (0-45%) cookies using an Instron Universal Testing Machine (Model 3201, Instron Corp., Canton, MA) equipped with a 5 kg load cell. Cookies were baked, cooled on wire racks for 2 h, and stored in plastic bags for 24 h before testing. Samples were placed on a platform and cut completely through with a stainless steel blade at a crosshead speed of 100 mm/min at a set distance of 25 cm. Shear force (kgF) was recorded as a function of displacement (mm) and the maximum force (kgF) was taken as a measure of hardness. Data were processed with Instron series IX software (Instron Corp., Canton, MA). All analyses were carried out in duplicate.

3.2.4.3. Colour determination

A Hunterlab (Labscan Spectrocolorimeter) LAB-XE Colour Difference Meter (Hunter Associates Laboratory Inc., Reston, VA) was utilized to measure colour of nine cookie formulations (0-45%) using concentrated barley protein for each day of the trained panel evaluations as well as each day of consumer panel evaluations. Three samples of each formulation were randomly selected from each evaluation and consumer testing day; triplicate readings were taken on each cookie by rotating each sample 120^0 three times. Results were expressed in "L" (0=black, 100=white), "a" (- =green, + =red) and "b" (- =blue, + =yellow) values. Calibration of the instrument was performed using a white tile with known values of "L" (91.66), "a" (-1.00), and "b" (-0.02).

3.2.5. Sensory evaluation

3.2.5.1. Trained panel

Ethics approval to conduct this research with human subjects was obtained from the Human Research Ethics Board of the Faculty of Agriculture, Forestry, and Home Economics. Standard sensory procedures were followed during recruitment, selection and training of sensory judges (ASTM, 1979; Meilgaard and others, 1991). Fifty five potential panelists were recruited from students and staff at the University of Alberta who responded to posted announcements. Panelists were screened using a scaling test, ranking of 4 sucrose solutions, basic taste identification tests, and descriptive analysis scenario questionnaire, followed by PROP test. Samples of the screening ballots are presented in Appendix 1 (Meilgaard and others, 1991). Ten panelists were selected and nine panelists completed training for six weeks. Training took place in the Sensory Evaluation Room in the Agriculture/Forestry Building. Training sessions were 1 h in duration four times a week for 5 weeks with the 6^{th} week used for product evaluations. Panelists were trained using repeated round table discussions in a focus group setting to become familiar with the use of a 15 cm line scale used to evaluate their sample attributes. During focus group setting the panelists decided on the dominant attributes of cookies fortified with concentrated barley protein and selected corresponding reference standards for these attributes. Reference standards and their respective scores are given in Table 3.2. Panelists also agreed on definitions and standardized tasting techniques for each attribute

as presented in Table 3.2. Quantitative descriptive analysis (QDA®; Stone and Sidel, 2004) was followed along with ISO Standard (1993, 1994).

Panelists evaluated all nine samples each day for a total of three consecutive days. Evaluations were conducted in individual standard sensory panel booths with fluorescent lighting using a 15 cm line scale that was anchored at 1.0 cm and 14.0 cm and marked with reference points. Sample evaluations were performed utilizing Compusense software, Version 5.0 (Compusense, Inc. 1999, Guelph, ON). Samples labeled with three digit codes were presented according to a random order, balanced design (Williams, 1949). Samples along with room temperature club soda for cleansing palate in-between samples and a napkin were presented on an off-white fiberglass tray. Trained panelists evaluated aroma, sweetness, saltiness, chewiness, cohesiveness, toothpack, and mouth coat for all 9 cookie formulations.

Table 3.2 Attributes, definitions, reference standards and scores for trained panel evaluations

Attribute	Definition	Reference Standard	Score[1]
Aroma	Grain complex	Pot barley	9.34
Sweetness	Taste on tongue stimulated by sugars and sweeteners	Sucrose solution (1.0%)	4.05
Saltiness	Taste on tongue associated with sodium chloride	Sodium chloride solution (0.35%)	4.94
Grain complex	Grain complex	Heinz barley baby cereal	6.66
Cohesiveness	Degree to which cookie mass holds together	One bite brownie	2.87
Cohesiveness	Degree to which cookie mass holds together	Multigrain Cheerios cereal	10.2
Toothpack	Amount of sample stuck in molars	Graham cracker	7.17
Mouthcoat	The residue texture left on mouth surface after swallowing	Digestive biscuit	8.00
Chewiness	The amount of energy required to chew the cookie to a state ready for swallowing: a product of hardness, cohesiveness, and springiness	Cooked macaroni	5.8

[1]Score on 15 cm line scale.

3.2.5.2. Consumer panel

Ethics approval was received from the Human Research Ethics Board of the Faculty of Agriculture, Forestry and Home Economics to conduct consumer panel evaluation of cookies made with concentrated barley protein. Most participants were recruited via e-mail largely from a consumer panel database via e-mail. The consumer data base is part of the sensory testing group at the University of Alberta. Additional participants were recruited by way of poster and/or word of mouth on the University

Alberta Campus and surrounding area. The poster advertisement is shown in Appendix 2. Consumer evaluations were performed in the Sensory Evaluation Room located in the Agriculture/Forestry Centre at the University of Alberta. Criteria to participate in the study were being 18 years of age or older, cognitively able to participate with adequate literacy skills, no sensitivities, intolerances, or allergies to cookie ingredients, barley, or club soda.

The consumer panel consisted of 116 university staff and students. Informed consent was collected prior to the evaluations. Consumer evaluations were performed in standard sensory booths with fluorescent lighting. Sample evaluations were performed utilizing Compusense software, Version 5.0 (Compusense, Inc. 1999, Guelph, ON). Consumers were asked to evaluate the cookies using standard procedures (Meilgaard et al., 1991) on a 9 point hedonic scale for overall opinion (1= dislike extremely to 9= like extremely). An example of the evaluation score card and demographic questionnaire is given in Appendix 3. The first 5 samples were presented in a random order presentation, balanced design (Williams, 1949) in a 12.5cm Styrofoam dish with a plastic lid. Both dish and lid were labeled with a three digit code and presented on an off-white fiberglass tray with a napkin, glass of room temperature club soda, and pencil. Consumers were then asked to complete the demographic questionnaire on paper before receiving the second tray with the remaining 4 samples in the same manner as the first 5 samples.

3.2.6. Statistical analysis

Trained panel evaluations and the associated instrumental measures were replicated

three times and the mean results are reported. Analysis of variance of proximate analysis, color, compression tests, trained sensory panel, and consumer panel results were done using SPSS Statistical Software, Version 13.0.1 (SPSS Institute Inc.). A complete randomized design was used to determine main effects. Means were compared by Tukey's test at a significance level of $p \leq 0.05$. Pearson correlation analysis between sensory attributes and instrumental measures were performed using SPSS CORR procedure. Principle components analyses were carried out on nine variables including: aroma, sweetness, saltiness, cereal flavour, cohesiveness, chewiness, toothpack, mouth coat, and overall acceptability. The data were analyzed by Factor Analysis PCA using SPSS Statistical Software, Version 13.0.1 (SPSS Institute, Inc.).

3.3. Results and Discussion

3.3.1. Proximate analysis

Composition analysis results for concentrated barley protein are presented in Table 3.3. The concentrated barley protein obtained in the pilot plant was lower in protein content (32.67%) and recovery (30 – 40%) as compared to those of Lekhi (2004) who obtained maximum protein purity of 70-82% and recovery of 66-74% at pH 11 and 23°C using 0.035M NaOH with lab scale extraction. Due to the low purity the protein fraction will be referred to as 'concentrated barley protein' as opposed to 'barley protein concentrate,' which implies the industry standard of having 65-75% protein. The pilot scale extraction for this study was carried out in a one step process to recover the protein-enriched fraction whereas previous pilot scale extractions for barley have focused mainly

on obtaining the beta-glucan fraction. Difficulties in the decanter step caused decreased yield and purity that resulted in higher ash (13.21%) and beta-glucan (12.65%) contents than anticipated. Erkan and others (2005) reported that the hulless barley flour used to make tarhana had the highest ash, protein and beta-glucan contents of 1.31%, 13.4% and 4.25%, respectively.

Table 3.3 Proximate analysis of concentrated barley protein fraction [1]

	% (w/w)
Moisture	6.44
Ash	13.21
Starch	22.65
Beta glucan	12.65
Fat	0.50
Protein	32.76

[1] Analyses carried out in duplicate and means presented.

Proximate analysis results of whole cookies are presented in Table 3.4, which indicate that moisture and lipid contents were similar ($p>0.05$) among all 9 treatments. As expected, protein levels increased ($p\leq0.05$) as % substitution increased, with treatments 15% and 20% being similar ($p>0.05$) as well as 30%, 35%, and 37.5% ($p>0.05$) treatments. Ash content also increased ($p\leq0.05$) as % protein concentrate increased, reflecting the high level of salt residue in the concentrated barley protein. Beta-glucan content similarly increased ($p\leq0.05$) with increasing protein concentrate addition in every treatment except for 35% and 37.5% treatments being similar ($p>0.05$). Therefore, the amount of beta-glucan remaining in the protein concentrate is an important factor in this product development. The starch content significantly ($p\leq0.05$) decreased with

increasing protein concentrate substitution, reflecting the fact that the concentrated protein containing 22.65% starch is used to replace wheat flour that normally has a starch content of 72% (w/w). McWatters (1978) reported that total protein content increased approximately 1.5% with peanut and soybean flour substitutions and that 30% substitution yielded twice as much protein as the control wheat flour cookie. In this study, the total protein content was only increased by 2.7% over the original wheat flour formulation at 45% substitution due to the low purity of concentrated protein used.

Table 3.4 Proximate analysis of cookie treatments[1].

Substitution (%)	Moisture (%w/w)	Ash (%w/w)	Lipid (%w/w)	Protein (%w/w)	Beta glucan (%w/w)	Starch (%w/w)
0	4.1	0.7^{a}	32.0^{a}	7.1^{a}	0.8^{a}	26.5^{a}
15	4.4	1.4^{b}	31.9^{a}	8.0^{b}	$.7^{b}$	24.9^{ab}
20	4.6	1.6^{c}	31.9^{a}	8.3^{bc}	1.0^{c}	23.9^{bc}
25	5.0	1.8^{d}	$31.8.^{a}$	8.6^{c}	1.1^{d}	22.1^{cd}
30	5.1	2.1^{e}	31.8^{a}	8.9^{d}	1.4^{e}	21.3^{de}
35	5.1	2.3^{f}	31.8^{a}	9.2^{d}	1.7^{f}	20.1^{def}
37.5	5.1	2.4^{g}	32.3^{a}	9.2^{d}	1.7^{f}	19.9^{def}
40	5.1	2.5^{h}	31.8^{a}	9.5^{e}	1.9^{g}	19.9^{def}
45	5.2	2.7^{i}	31.9^{a}	9.8^{e}	2.1^{h}	18.4^{f}

[1] Samples run in duplicate and means reported.
[a-f] Means in the same column with different letters are significantly different at $p \leq 0.05$.

3.3.2. Instrumental analyses

3.3.2.1. Cookie dough

Compression force vs displacement curves of cookie dough treatments (0%, 15%, 25%, and 45%) are illustrated in Figure 3.2. The control (0%) was significantly different from all concentrated barley protein cookie treatments.

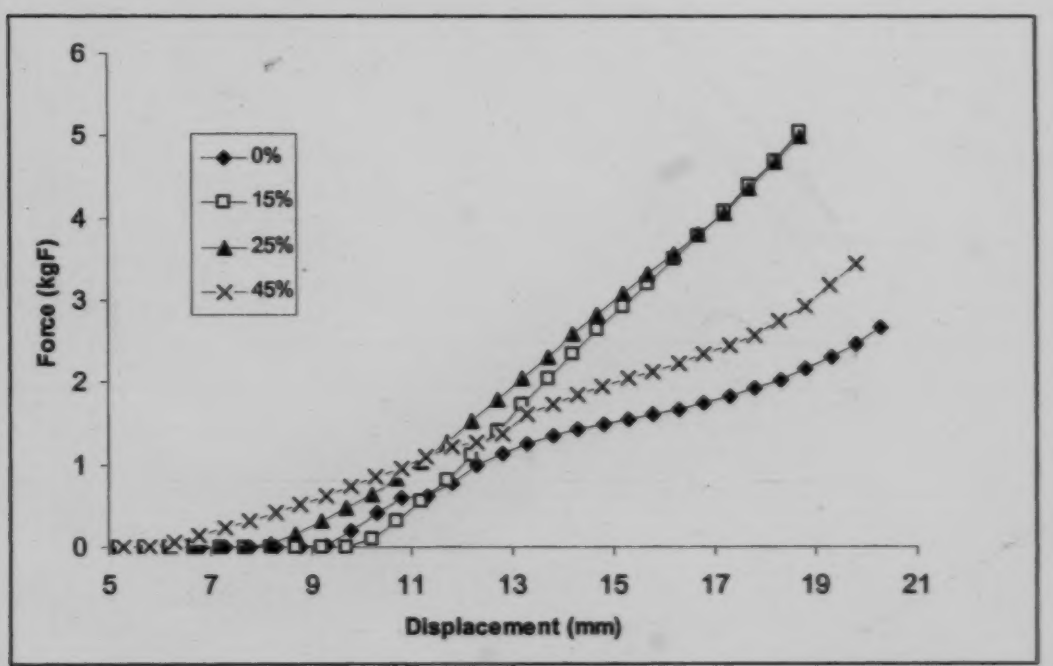


Figure 3.2 Representative compression force vs displacement curves for cookie dough with 0%,15%, 25%, and 45% concentrated barley protein substitution.

The average maximum force values for cookie dough are presented in Table 3.5. The 0% cookie dough sample was significantly ($p \leq 0.05$) different from other dough samples and required the least amount of force to compress to 50% of its original height. A similar force ($p > 0.5$) was required to compress the 15% and 25% as compared to the

45% cookie dough. There is enough available water in the formulation to form a strong protein network with the 15% and 25%; however, when the protein amount increases to 45% there is not enough water to hydrate the proteins resulting in a decrease ($p \leq 0.05$) in maximum force that can be related to weaker protein network formed.

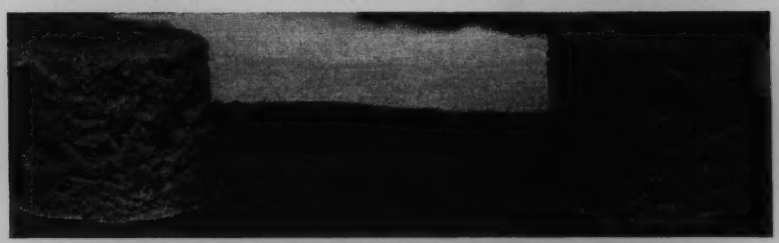
Table 3.5 Maximum force for cookie dough prepared with 0%, 15%, 25%, 45% flour substitution with concentrated barley protein.

% Substitution	Maximum Force (kgF)
0	3.42[a]
15	4.95[c]
25	4.94[c]
45	4.70[b]
SEM[2]	0.03

[1] All measurements were performed in duplicate.
[a-c] Means with different letters are significantly different ($p \leq 0.05$).
[2] Standard error of the mean.

Figure 3.3 is a photograph of barley dough samples before and after compression. This photograph reveals that the barley dough treatments held their shape and form and reveal characteristics of "springiness" after compression. On the other hand, the 0% control compared to the 15% barley (Figure 3.4) remained deformed and showed "plastic" characteristics. The difference seen between 0% and the 15% barley is due to the increased protein network as well as the increase in beta-glucan, which contributes and reinforces a stronger network.

a) Barley dough before compression.



b) Barley dough after compression.

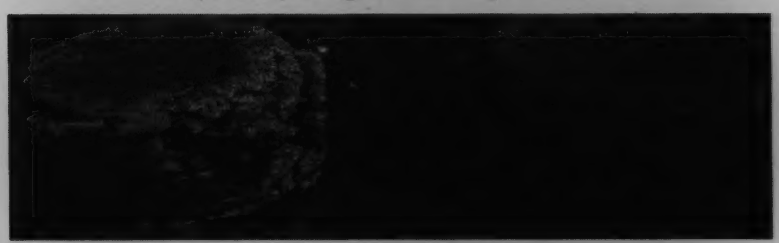


Figure 3.3 Photograph of 45% (left) 15% (right) barley dough before (a) and after (b) compression.

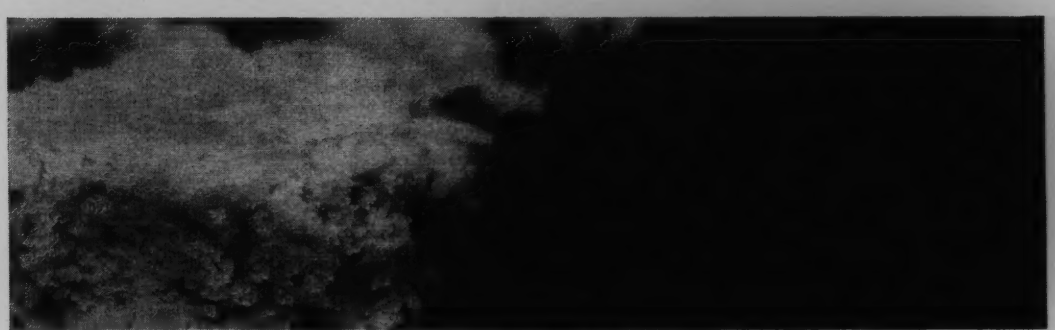


Figure 3.4 Photograph of cookie doughs after compression testing: 0% control treatment (left), 15% barley treatment (right).

3.3.2.2. Whole cookie

Figure 3.5 and Figure 3.6 depict the shear force vs. displacement curves for the 9 treatments. The control cookie (0%) was significantly ($p \leq 0.05$) different from all treatments (15-45%), which yielded similar force vs. displacement curves. Zoulias and others (2000) found that cookies with fat mimetics at 35% fat replacement had significantly higher peak force than the control with Dairytrim® and polydextrose. James and others (1989) also found that cookies with rice bran-soy blend formulation had increased hardness and chewiness. Other researchers (Gaines, 1992; Perry and others, 2003; Swanson and others 2003) have used instrumental probing or three-bean technique to assess textural attributes such as hardness and fracturability of cookies. Their findings indicate a good correlation between instrumental measures and sensory results through probing. In the present study, probing was not carried out due to the smaller size of each cookie (3 cm width x 5 cm length) and repeated probing into one sample was not tolerated due to cracking and crumbling of samples.

There was no significant difference ($p > 0.05$) between the maximum force values obtained by shear force testing of cookie treatments (0- 45%) on the three days of evaluations by trained panel or between consumer evaluations; therefore, consistency and reliability within baking was confirmed. There was a significant ($p \leq 0.05$) difference between 0% treatment and all remaining treatments (15-45%) as demonstrated in Table 3.6. The 45% treatment produced a harder cookie, which required more force to cut due to internal cohesiveness and springiness. These attributes can be explained mainly based on the high beta-glucan content and formation of a stronger internal protein matrix. The

texture of cookies encompasses the moisture, the crumb size and shape along with the internal stresses produced during baking and cooling (Maltz, 1962). Peak force represents the maximum resistance against the cutting blade and occurs when the sample starts to break (Zoulias and others, 2000). Product hardness is the maximum force at break (Gaines, 1994). Therefore, maximum force value relates to hardness of cookies, indicating that using the concentrated barley protein increased the hardness of the particular type of cookie used in this study.

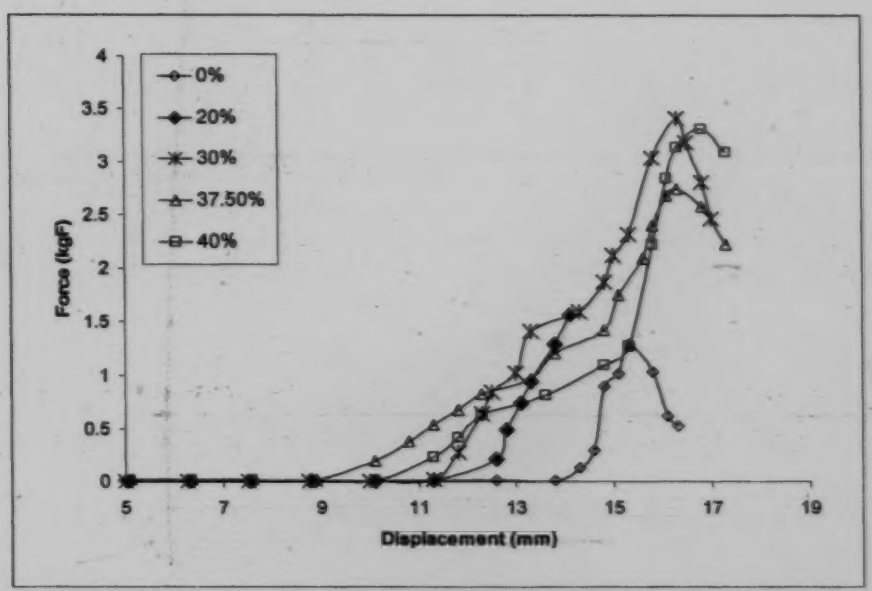


Figure 3.5 Representative shear force vs displacement curve for cookies prepared with 0%, 20%, 30%, 37.5%, and 40% barley protein substitution.

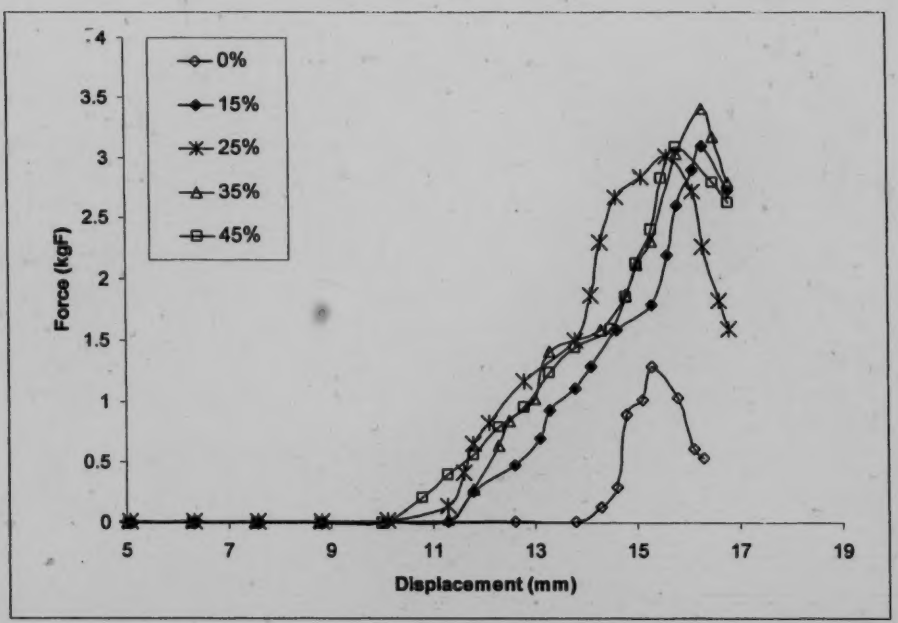


Figure 3.6 Representative shear force vs displacement curves for cookies prepared with 0%, 15%, 25%, 35%, and 45% concentrated barley protein substitution.

Kramer (1951) stated that the maximum force generated during the shearing cycle is an indication of texture, but that shear itself appears not to identify any single cookie or cracker texture element. The 0% cookie had the lowest peak force indicating that the control cookie was more tender.

Table 3.6 Maximum force for whole cookies

Treatment (%)	Max force (kgF)
0	1.48[a]
15	2.55[b]
20	2.61[b]
25	2.68[b]
30	3.00[c]
35	3.00[c]
37.5	3.11[c]
40	3.29[c]
45	3.55[d]
SEM[1]	0.07

[a-c] Means with different letters are significantly different ($p \leq 0.05$).
[1] Standard error of the mean.

3.3.2.3. Cookie spread

All cookies widths and thicknesses were significantly ($p \leq 0.05$) different from each other as displayed in Table 3.7. The control cookie treatment (0%) had the largest width and the smallest thickness. Adding any amount of concentrated barley protein significantly ($p \leq 0.05$) changed these measurements, indicating that the barley protein fraction forms a strong network, which sets the cookie prior to spreading out. The smallest level of substitution tested (15%) had the thickest measurement and the smallest spread, while the treatments 15% and 25% were similar in spread ($p > 0.05$).

Table 3.7 Width, thickness, and spread of cookies prepared with concentrated barley protein.

Treatment (% substitution)	Width (mm)	Thickness (mm)	Spread (ratio)
0	40.20±.01[d]	6.60±.00[a]	60.90±.00[c]
15	37.10±.12[c]	8.35±.17[d]	43.25±.64[a]
25	35.80±.23[b]	8.00±.12[c]	43.40±.35[a]
45	34.90±.00[a]	7.50±.00[b]	45.00±.00[b]

[a-d] Means in the same column with different letters are significantly ($p \leq 0.05$) different.

Figure 3.7 is a photograph, which reveals the difference in widths between 15%, 25%, and 45% cookies. The width was significantly ($p \leq 0.05$) different among all treatments; width decreased as the percentage of concentrated barley protein increased. Dough with lower glass transition temperature yields smaller diameter cookies (Slade and Leuir 1994; Singh and others 2002). The glass transition temperature is the temperature at which the dough changes from visco-elastic network to a collapsible film. In the current study, the concentrated barley protein keeps the dough at the visco-elastic state and does not allow the dough to collapse and spread. Thus, it can be concluded that concentrated barley protein affects the glass transition temperature, negatively impacting the spread. One could predict that incorporating an emulsifier with the concentrated barley protein might improve the spread factor. The thickness was also significantly ($p \leq 0.05$) different among all treatments indicating that the concentrated barley protein forms a network, which holds any carbon dioxide produced while baking. The control cookie had the largest spread value. The 15% treatment yielded the smallest spread, second largest width, with largest thickness. These findings are in agreement with those of Ordorica-

Falomire and Paredes-Lopez (1991), and Claughton and Pearce (1989) who also found a reduction in spread factor with enrichment of cookies with sunflower protein. James and others (1989) also found a decrease in spread using rice bran and soy protein even with the addition of extra water, shortening, and/or emulsifier.

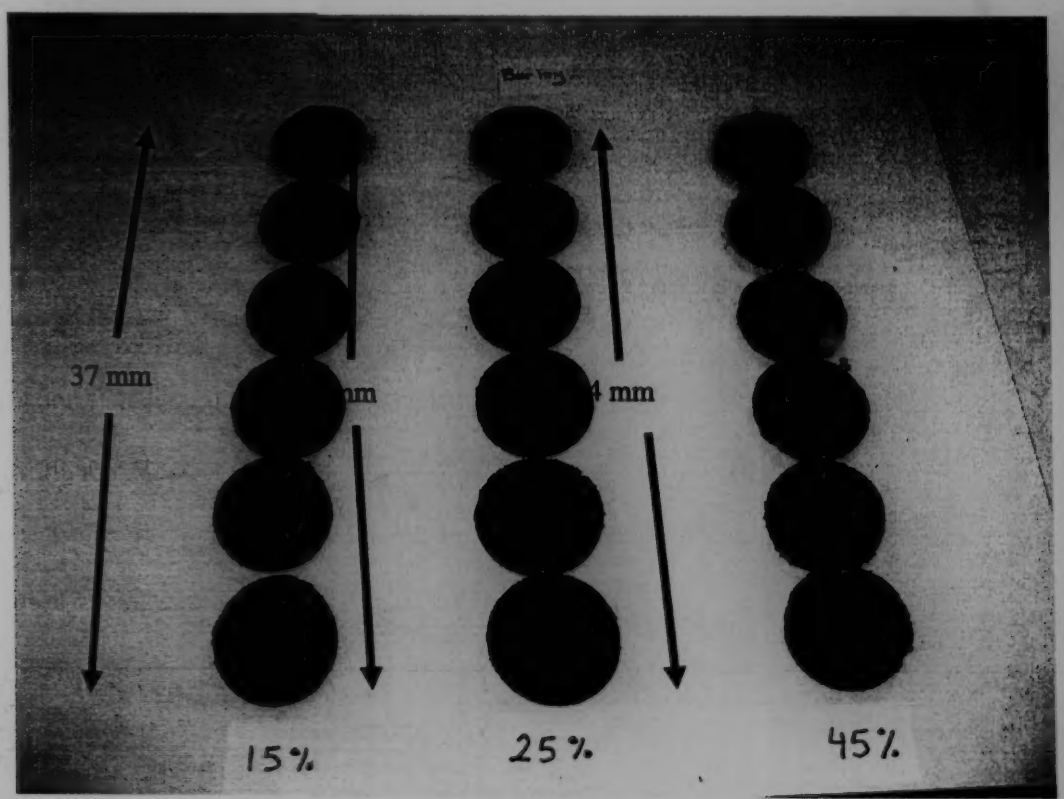


Figure 3.7 Photograph of cookie spread treatments with 15%, 25%, and 45% flour substitution.

Fuhr (1962) suggested that the spread factor is affected by competition of other ingredients for water absorption. Lekhi (2004) reported the water absorption of concentrated barley protein to be high, which in part explains the decrease in spread;

however, one would expect that as the protein concentration increases the spread would also decrease, but the current findings clearly show the smallest spread is with 15% treatment and then increases. Ordorica-Falomire and Paredes-Lopez (1991) reported that the spread factor for cookies with safflower isoelectric precipitated protein (IP) showed a similar trend where the cookie with the smallest level of addition (20%) had the smallest spread factor and concluded that other functional properties of proteins may also affect the spread. The current findings agree with those of Falomire and Lopez (1991) and the concentrated barley protein used in this study was also obtained through isoelectric precipitation. Zoulias and others (2000) also reported that pectin, maltodextrins and beta-glucan seem to act as a secondary source of network formation contributing to the gluten network and exaggerating the elastic shrinkage thus resulting in cookies with smaller diameter. The concentrated barley protein used in this study had a high beta-glucan content (12.65%) and resulted in cookies with a smaller diameter, which is in agreement with Zoulias and others (2002).

3.3.2.4. Colour

Hunter colour values are reported in Table 3.8. As the level of concentrated barley protein is increased in the cookie formulation, the cookies become dark as indicated by a significant ($p \leq 0.05$) drop in "L" value (71 to 45, for 0% to 45% substitution, respectively). Lorenz (1983) also noted that the color of cookies became darker with increasing amounts of sunflower meal as well as with fababean protein concentrate There is also a significant ($p \leq 0.05$) difference in the redness "a" and yellowness "b" values. As

the level of concentrated barley protein increased the redness value also increased. The Maillard reactions, non-enzymatic browning, that take place during baking involve the interaction of reducing sugars with proteins, resulting in reddish-brown hues (Manley, 1991). The control cookie showed no redness (-0.68); however, it was the highest ($p \leq 0.5$) in yellowness at 19.57. The fact that the 0% treatment had the protein content only of the wheat flour (7.1%) compared to that of cookies with increasing concentrated barley protein (8.0% - 9.8%) supports the lack of reddish brown hues in the control cookie.

Table 3.8 Hunter colour values for the cookies prepared with concentrated barley protein.

Treatments (% substitution)	L[1]	a[2]	b[3]
0	71.85^{f}	-0.68^{e}	19.57^{d}
15	56.21^{e}	3.68^{d}	16.19^{c}
20	53.61^{de}	3.84^{d}	15.42^{bc}
25	51.87^{d}	4.00^{c}	15.00^{b}
30	51.03^{c}	4.36^{bc}	15.05^{b}
35	48.65^{bc}	4.43^{b}	14.56^{ab}
37.5	48.01^{ab}	4.48^{b}	14.48^{ab}
40	47.78^{ab}	4.64^{b}	15.50^{bc}
45	45.46^{a}	5.34^{a}	13.84^{a}

[a-e] Means in the same column with the same letter are not significantly different at ($p > 0.05$)
[1] L = lightness to darkness value (100 white, 0 black)
[2] a = red to green value (+ red, - green)
[3] b = yellow to blue value (+yellow, - blue)

3.3.3. Sensory evaluation

3.3.3.1. Trained panel

Judges were tested and confirmed for reliability and validity for three consecutive days prior to sample evaluations. Results from the trained panel sensory evaluation as presented in Figure 3.8 and Figure 3.9 clearly show that as the protein concentration increased the intensity of all attributes (aroma, saltiness, cereal flavour, chewiness, cohesiveness, toothpack, mouthcoat) ($p \leq 0.05$) increased except for sweetness, which decreased ($p \leq 0.05$). Trained panel evaluation scores found in Table 3.9 indicate that aroma, sweetness, saltiness, cereal flavour, chewiness, cohesiveness, toothpack, mouthcoat for the control cookie (0%) are significantly ($p \leq 0.05$) different from those of all other treatments. The 45% treatment is different ($p \leq 0.05$) for sweetness and cohesiveness from all other treatments. There appears to be some grouping effect in that 15% and 20% treatments are similar ($p > 0.05$) for all attributes except for saltiness and cereal flavour. Then, there is a difference at either 20% or 25%, which could be inferred as the "cut-off" point for the addition of concentrated barley protein into this particular sugar cookie recipe as perceived by the trained sensory panel, since there was a significant difference in the majority of the attributes above this point. Lorenz (1983) found that 15% fababean protein concentrate was less acceptable noting a bitter aftertaste, whereas 10% substitution was acceptable.

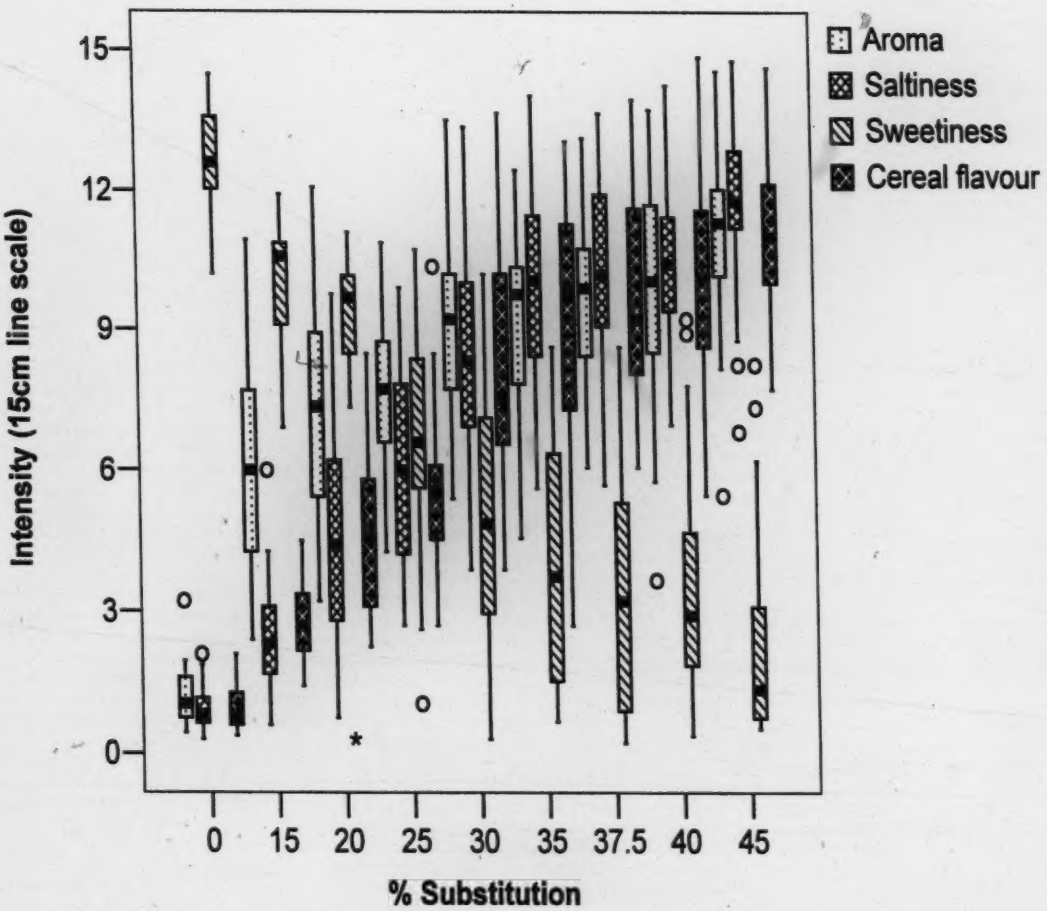


Figure 3.8 Aroma, saltiness, sweetness, and cereal flavour intensity determined by trained panel for cookies prepared with 0-45% flour substitution with concentrated barley protein

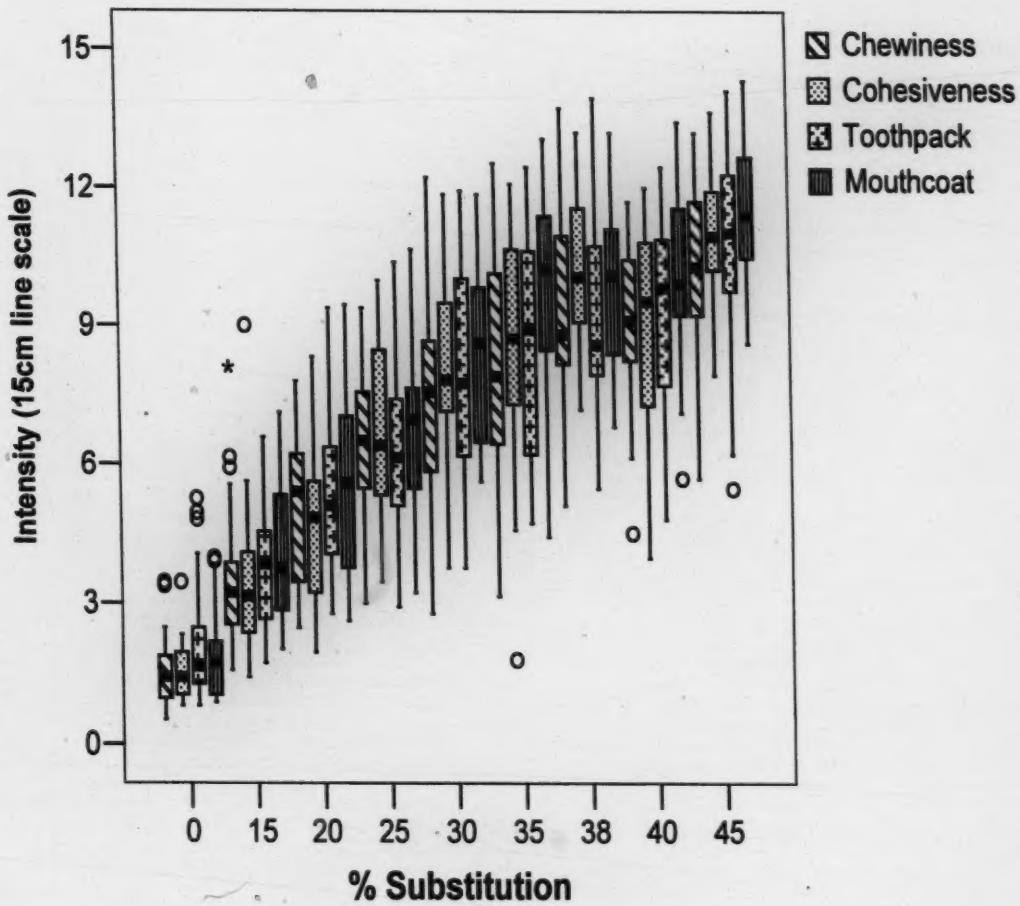


Figure 3.9 Chewiness, cohesiveness, toothpack and mouthcoat intensity determined by trained panel for cookies prepared with 0-45% flour substitution with concentrated barley protein.

Lorenz (1983) noted grittiness at low levels of 5% substitution for millet flours that was unacceptable by sensory evaluation, which was attributed to the high ash content of flour, whereas the fababean at 15% substitution did not contribute to grittiness even though the protein concentrate also had high ash content. There were no adverse effects in terms of grittiness according to the trained panel in this study. Grittiness is mainly related to particle size, ease of hydration of particles, and mouthfeel, which were not determined in the current study.

Table 3.9 Trained panel sensory evaluation results for all cookie treatments (0-45%)

Attribute	0	15	20	25	30	35	37.5	40	45
Aroma	1.11^{a}	6.10^{b}	7.26^{b}	7.70^{bc}	9.07^{cd}	9.31^{cd}	9.60^{d}	9.91^{de}	11.30^{e}
Sweetness	12.70^{a}	10.02^{b}	9.42^{b}	6.63^{c}	5.13^{cd}	4.25^{de}	3.16^{ef}	3.37^{de}	2.18^{f}
Saltiness	0.88^{a}	2.48^{a}	4.72^{b}	6.00^{b}	8.57^{c}	9.90^{cd}	10.31^{de}	10.48^{de}	11.88^{e}
Cereal Flavour	0.93^{a}	2.77^{b}	4.62^{c}	5.50^{c}	8.11^{d}	9.08^{de}	9.83^{ef}	10.25^{ef}	11.06^{f}
Chewiness	1.58^{a}	3.57^{b}	4.78^{b}	6.33^{c}	7.74^{cd}	8.49^{de}	9.44^{def}	9.09^{def}	10.33^{f}
Cohesiveness	1.53^{a}	3.50^{b}	4.61^{b}	6.57^{c}	8.41^{d}	8.86^{de}	10.18^{ef}	9.10^{de}	11.03^{f}
Toothpack	2.23^{a}	3.89^{ab}	5.24^{bc}	6.31^{c}	8.05^{d}	8.64^{d}	9.18^{de}	9.35^{de}	10.64^{e}
Mouthcoat	1.92^{a}	4.09^{b}	5.64^{bc}	6.89^{cd}	8.35^{de}	9.62^{ef}	9.89^{ef}	10.09^{fg}	11.51^{g}

$^{a-g}$ Means with different letters in each row are significantly different at $p \leq 0.05$.

Ordorica-Falomir and Paredes-Lopez (1991) reported that cookies enriched with isoelectrically precipitated safflower meal prepared in the laboratory or from an industrial setting at all levels of enrichment had significantly different scores for texture, colour, and flavour compared to the control. However, safflower protein isolates prepared by

micellation rather than isoelectric precipitation resulted in cookies similar to the control at all levels of enrichment. Thus, they concluded that incorporation of safflower protein isolates prepared by micellization was possible without any loss of physical or sensory properties of cookies. The current study uses proteins obtained through isoelectric precipitation; therefore, if could be valuable to determine if barley protein isolates could be obtained by micellization to minimize textural and flavour attributes in cookie formulations. Giami and Barber (2004) studied the incorporation of protein concentrates from fluted pumpkin seeds in cookie formulations and found that incorporation at 15% level of protein from un-germinated fluted pumpkin seeds resulted in cookies similar to control cookies, whereas the cookies supplemented with concentrates from germinated seeds at levels between 15-25% were unacceptable for colour, texture and flavour.

Pearson correlation results of the trained panel and instrumental measures indicate that all attributes were significantly ($p \leq 0.01$) correlated (Table 3.11). Chewiness was correlated ($p \leq 0.05$) to thickness, spread, and maximum force. Toothpack was correlated ($p \leq 0.05$) to thickness and spread suggesting that beta-glucan was responsible for increased gumminess relating to toothpack. Correlation coefficients indicate practicality of instrumental methods relative to sensory measurements (Gaines, 1994). Correlations specify if two sets of values are related; it does not model interactions or imply causality, whereas linear regression defines if two or more variables are interrelated. Linear regression equations were established for each attribute (aroma, sweetness, saltiness, cereal flavour, chewiness, cohesiveness, mouth coat, toothpack) as a function of percentage substitution. All coefficients and constants (Table 3.10) were significant

($p \leq 0.05$). The R^2 values were in the range of 0.64 – 0.75. High R^2 values close to 1 are desirable to demonstrate the goodness of fit of experimental data. Other models including quadratic, cubic, inverse, and logarithmic transformation of variables were also tested but did not improve the R^2 values.

Human sensory responses are not linear and at extreme levels of either high or low there will be an expected increase in variance. Peleg (1980) indicated there would be better correlations with sensory sensitivity and instrumental data in the middle of the texture range. In this study, a wide range of treatments (0% to 45%) has been investigated and these results provide correlation with Peleg that at the extremes, more so at the high end (45%) there tends to be more variation in sensory analysis.

Table 3.10 Linear regression[1] parameters for cookie attributes as a function of % substitution based on trained panel evaluations

Attribute	R-squared	Constant (a)	Coefficient (b)
Aroma	0.649	2.27	0.205
Saltiness	0.749	-0.183	0.269
Sweetness	0.704	13.31	-0.253
Cereal Flavour	0.722	-0.004	0.250
Chewiness	0.690	1.14	0.206
Cohesiveness	0.707	0.950	0.222
Mouthcoat	0.733	1.38	0.224
Toothpack	0.636	1.63	0.197

[1] attribute=a+b (%substitution).

Table 3.10 Pearson correlation of trained sensory panel and instrumental measures

Correlation	Aroma	Salt	Sweet	Cereal	Chew	Cohe-sive	Tooth-pack	Mouth-coat	Width	Thick	Spread	Max. force	L	a	b
Aroma	1	0.713**	-0.694**	0.768**	0.705**	0.712**	0.711**	0.732**	0.187	-0.350	0.326	-0.310	-0.021	0.045	0.018
Salt	0.713**	1	-0.844**	0.894**	0.825**	0.832**	0.796**	0.835**	0.331	-0.373	0.418	-0.378	0.037	-0.052	0.016
Sweet	-.0694**	-0.844**	1	-0.867**	-0.781**	-0.794	-0.782**	-0.801**	-0.261	0.263	-0.309	0.299	-0.141-	0.145	-0.105
Cereal	0.768**	0.894**	-.867**	1	0.835**	0.837**	0.817**	0.864**	0.293	-0.372	0.401	-0.356	0.079	-0.079	0.067
Chew	0.705**	0.825**	-0.871**	-0.835**	1	0.890**	0.841**	0.860**	0.351	-0.643*	0.605*	-0.551*	0.088	-0.045	0.080
Cohesive	0.712**	0.832**	-0.794**	0.837**	0.890**	1	0.838**	0.842**	0.397	-0.364	0.477	-0.355	0.088	-0.077	0.075
Toothpack	0.711**	0.796**	-0.782**	0.817**	0.841**	0.838**	1	0.921**	0.359	-0.592*	0.577*	-0.510	0.052	-0.013	0.040
Mouthcoat	0.732**	0.835**	-0.801**	0.864**	0.860**	0.842**	0.921**	1	0.273	-0.490	0.466	-0.420	0.045	-0.037	0.016
Width	0.187	0.331	-0.261	0.293	0.352	0.397	0.359	0.273	1	-0.433	0.809**	-0.745**	-0.064	-0.071	-0.153
Thickness	-0.350	-0.373	0.263	-0.372	-0.643*	-0.364	-0.592*	-0.490	-0.433	1	-0.880**	0.867**	0.753**	-0.684**	0.788**
Spread	0.326	0.418	-0.309	0.401	0.065*	0.447	0.577*	0.466	0.809**	-0.880	1	-0.960**	-0.529	0.413	-0.594*
Max force	-0.310	-0.378	0.299	-0.356	-0.511*	-0.355	-0.510	-0.420	-0.745**	0.867**	-0.960**	1	0.546*	-0.440	0.626*
L	-0.021	0.037	-0.141	0.079	0.088	0.088	0.052	0.045	-0.064	0.753**	-0.529	0.546*	1	-0.820**	0.889**
a	0.045	-0.052	0.145	-0.079	-0.045	-0.077	-0.013	-0.037	-0.071	-0.684**	0.413	-0.440	-0.820**	1	-0.566**
b	0.018	0.016	-0.105	0.067	0.080	0.075	0.040	0.016	-0.153	0.788**	-0.594*	0.626*	0.889**	-0.566**	1

** significant at ($p \leq 0.01$), * significant at ($p \leq 0.05$).

3.3.3.2. Consumer panel

The consumer panel consisted of 116 panelists and the distribution of males and females with corresponding age categories is illustrated in Figure 3.10. The majority of the consumers were female and the major age group was 20 to 29 years of age.

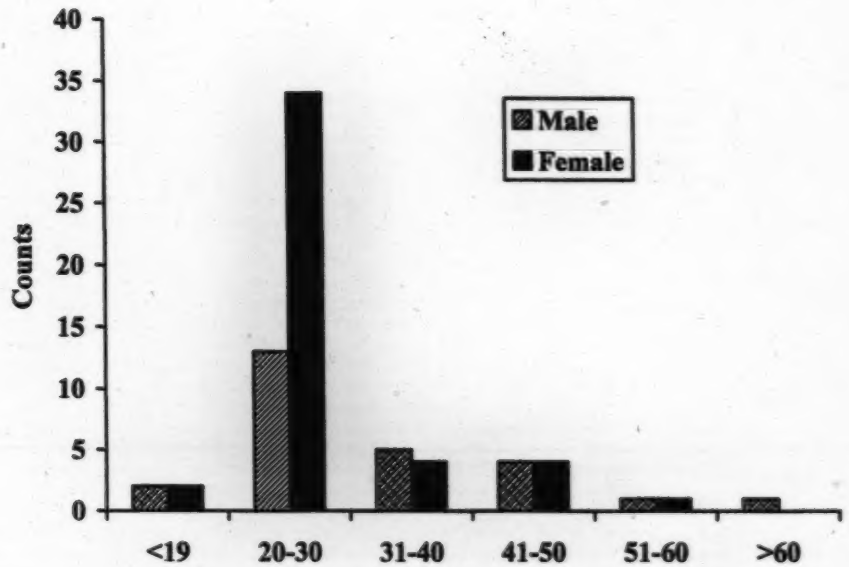


Figure 3.10 Consumer panel frequency of gender and age distribution.

There was no significant difference ($p>0.05$) in the overall opinion of consumer for cookies at 0-20% substitutions as indicated in Table 3.12. These cookie treatments were all rated as "like moderately" (7) on the 9 point hedonic scale. The overall opinion

of the 25% cookie was similar to that of the 20%, but lower ($p \leq 0.05$) than that of 0% and 15% cookie formulations statistically. Interpreting the whole numbers from the consumer opinion all formulations in the range 0-25% were rated as "like moderately" (7). The overall opinion of the cookie formulations 40% and 45% were significantly ($p \leq 0.05$) lower than those for all other formulations and were rated as "neither like nor dislike" (5). From a practical look at the overall opinion from the 9 point hedonic scale, treatments 37.5%, 40% and 45% were all rated as "neither like nor dislike" (5). There seems to be a cutoff point at 25% substitution at which the hedonic scores decrease and the threshold appears to fall at 37.5% when the liking falls to "neither like nor dislike".

Table 3.12 Consumer overall opinion for the cookie treatments.

Treatment (%substitution)	Overall opinion[1]
0	7.3 ± 1.4^{a}
15	7.2 ± 0.9^{a}
20	6.9 ± 1.2^{ab}
25	6.5 ± 1.6^{b}
30	5.8 ± 1.5^{c}
35	5.5 ± 1.7^{cd}
37.5	5.0 ± 1.8^{de}
40	4.8 ± 1.8^{e}
45	4.7 ± 1.8^{e}

[1]Mean ± std. dev on 9 point hedonic scale (9=like extremely, 1=dislike extremely).
[a-e] Means with different letters are significantly different at $p \leq 0.05$.

Consumer comments about the different cookie treatments are shown in Appendix 4. The frequency distributions of overall opinion scores for all treatments are illustrated in Figure 3.11. The graph reveals the overall skewness to the right for consumer acceptability. Cookies with lower substitution rates (15%, 20%, 25%) scored higher on the hedonic scale (6-9). However, the higher substitution rates (30 to 45%) scored lower on the hedonic scale (2 to 5), which is indicated with the skewness to the left in Figure 3.11 for these treatments.

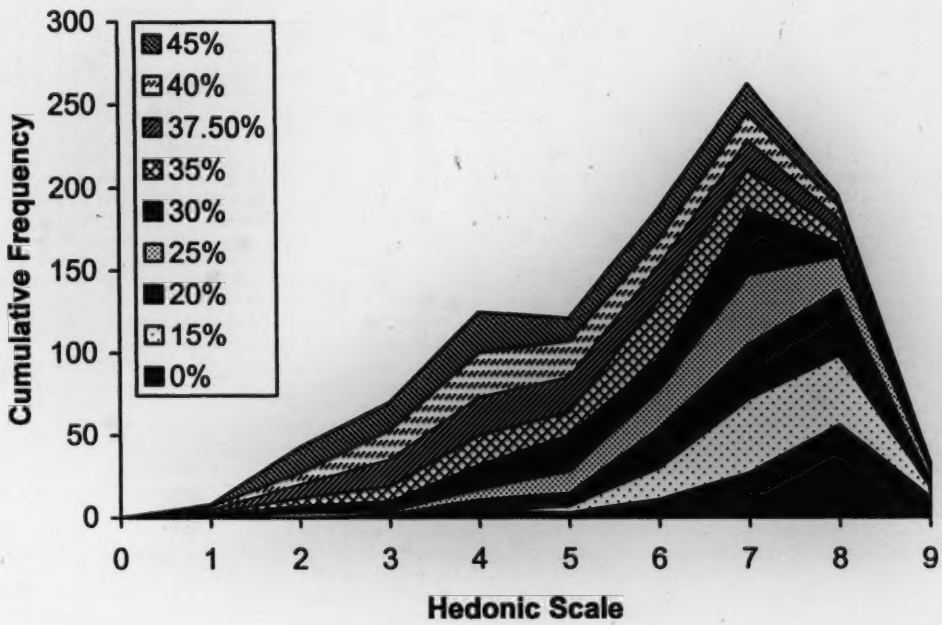


Figure 3.11 Cumulative frequency of consumer overall opinion of cookie treatments (0-45%) on hedonic scale (9=like extremely, 1=dislike extremely).

3.3.3.3. Principle components analysis

Principle components analysis for the trained and consumer panel results are shown in Table 3.13 for the first two principle components. The KMO sampling adequacy was 0.935 and the Bartlett's test of sphericity was significant ($p \leq 0.05$). The correlation matrix indicated that all attributes were significantly correlated ($p \leq 0.05$). The correlation matrix is recommended when the variables are measured in different scales (15 cm scale and 9 point hedonic scale) as the original variables are standardized to unit variance (Borgognone and others, 2001). Two significant principal components were extracted from the data describing 74.04% (PC1) and 11.20% (PC2) of the variation, respectively. The scree plot in Figure 3.12 visualizes the variation described by PC1 and PC2 where the proportion of variance described by the remainder of the components is relatively small. The component plot, Figure 3.13 reveals that sweetness explains the majority of the variation of all the treatments. Aroma, saltiness, cereal flavour, chewiness, cohesiveness, toothpack, and mouthcoat are all clustered closely together. Overall consumer opinion is influenced mainly by the sweetness of the sample.

In using such an analysis a minimum of 6 products are required using hedonic scales; consequently in this study a total of 9 products were evaluated to achieve a sufficient and adequate PCA analysis.

Table 3.13 Principle components eigen values for the PC1 and PC2.

Principle Component	Eigen value	Proportion of total variance (%)	Cumulative variance proportion (%)
PC 1	6.44	74.04	74.04
PC 2	1.01	11.20	85.24

Table 3.14 lists the component matrix for PC1 and PC2 for each attribute tested. Mouthcoat, cereal, chewiness, toothpack, saltiness, cohesiveness, and aroma all have values close +1 indicating they have a high influence on PC1. Sweetness (-0.897) is close to -1, which indicates a large influence in the opposite direction on PC1. Overall opinion (0.993) has the largest influence on PC2.

Table 3.14 Component matrix[1]

	Components	
	1	2
Mouth coat	0.939	
Cereal	0.939	
Chewiness	0.925	
Toothpack	0.924	-0.107
Saltiness	0.922	
Cohesiveness	0.921	
Sweetness	-0.897	
Aroma	0.823	
Overall opinion		0.993

[1]extraction method PC1 and PC2.

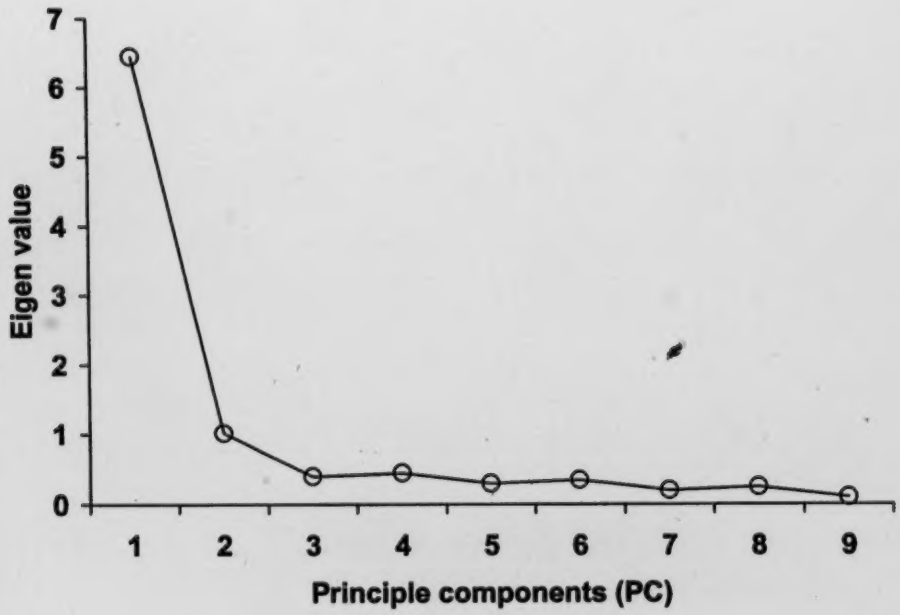


Figure 3.12 Scree plot: eigen value and principal components.

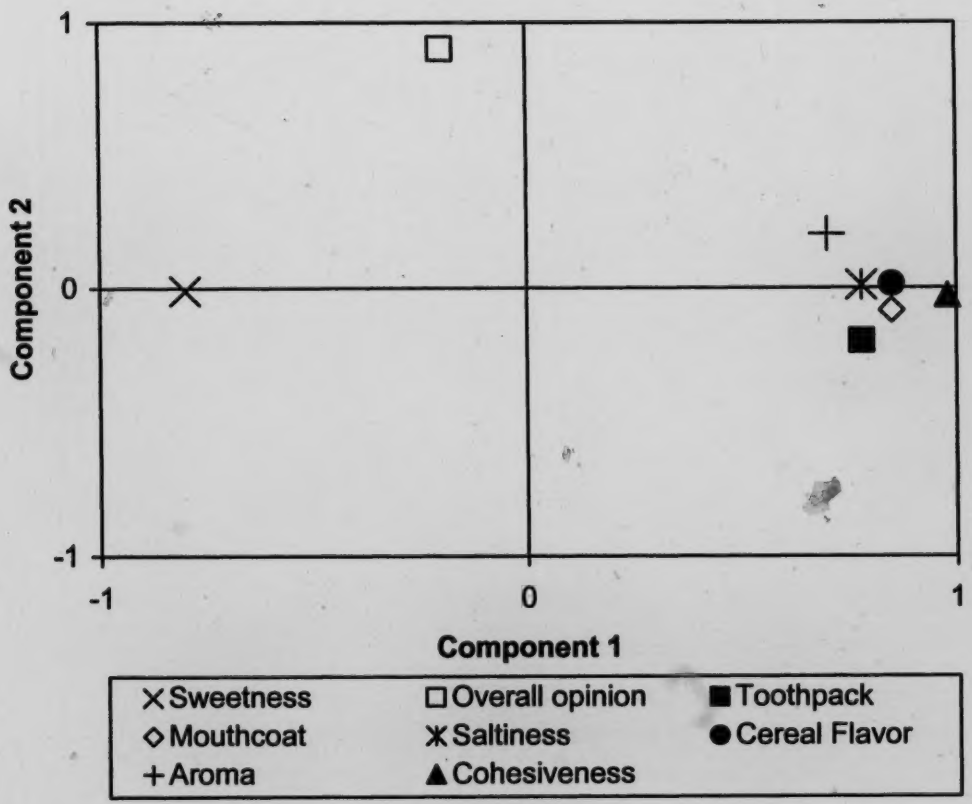


Figure 3.13 Principle components PC1 and PC2.

3.4. Conclusions

The protein content of cookies increased significantly ($p \leq 0.05$) upon substitution of wheat flour with concentrated barley protein at levels of 15–45%. The 15% dough treatment had the highest maximum force in compression testing while the 15% cookie treatment had the smallest spread. Due to formation of a strong internal network of protein and beta-glucan the cookies made with concentrated barley protein were harder and less tender than control cookies.

Reddish brown hues were predominant in cookies fortified with concentrated barley protein. Colour affects how consumers perceive taste; therefore, consideration of how protein concentrates affect visual senses is important.

Trained panelists found that as the level of concentrated barley protein was increased so did the saltiness, cereal flavour, and cereal aroma despite the fact that the amounts of other cookie ingredients were not altered, whereas the sweetness decreased. As for textural attributes (chewiness, cohesiveness, toothpack, and mouthcoat) the trained panelists found an increase in the intensity of all textural attributes with increased level of substitution. There was not as much discrimination found between samples from 30% to 40% level; whereas, larger differences were detected at lower substitution levels such as 15% to 25% as well as the high end of substitution (45%).

Consumers found the cookies substituted at 15% and 20% to be similar ($p>0.05$) to the control (0%); therefore, further investigation for supplementation starting at this level is recommended. Consumers rated the 0%, 15%, and 20% substitution cookies at "like moderately" (7.3, 7.2 and 6.9 respectively). PCA showed that the overall consumer opinion is influenced mainly by the sweetness of cookies.

The results indicate that concentrated barley protein can be successfully incorporated into a cookie product at a higher percent substitution level (15-20%) than reported previously at 5% using various protein concentrates.

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4. FORTIFICATION OF COOKIES USING CONCENTRATED BARLEY, OAT, AND SOY PROTEIN INGREDIENTS

4.1. Introduction

There has been a growing trend towards incorporating functional ingredients into everyday foods to increase health benefits for the aging population. Functional ingredients such as oats, namely rolled oats, oat bran and oat beta-glucan as well as soy are known by consumers for their "health-promoting ingredients. Common everyday foods can be fortified with such functional ingredients to enhance desired health benefits. Cookies have been modified to become "healthier" foods through reduced fat, reduced sugar, or increased fibre ingredients (Dougherty and others, 1988; Hudson and others, 1992; Mitzel and others, 1996; Drewnowski and others, 1998; Romanchick-Cerpovicz and others, 2002), but literature is lacking in terms of fortification of cookies with protein. Advantages of using cookies as a vehicle for fortification include wide consumption over a broad range of ages and good eating quality coupled with long shelf life (Tsen and others, 1973). Protein enrichment of cookies could provide additional nutrients for certain population groups such as children who can be picky eaters or for the elderly who may be protein malnourished.

[1]A version of this chapter is to be submitted to the Journal of. Food Quality and Preference for consideration for publication.

Soy flours, soy protein isolates and soy concentrates have been used in numerous studies for baked product fortification (Tsen and others, 1973; 1974; Sipos and others, 1974; Ashok and others, 2002) with acceptable outcomes at levels varying from 5 to 25% addition of soy. Oat as de-hulled flour has been investigated as a source of fibre in various baked and meat products (Dougherty and others, 1988; Hudson and others, 1992; Lapvetelainen and others, 1994; Duss and Nyber, 2004); conversely, a concentrated oat protein has not been used in any type of food or baked product application.

In order to capitalize on such functional ingredients, it is imperative to investigate food product applications of grain protein concentrates and understand their physical and functional characteristics in various food systems. A number of researchers have evaluated functional properties of protein concentrates and isolates from various sources such as barley (Lekhi, 2004), defatted wheat germ (Hettiarachchy, 1996), rice bran (Bera, 1989) and canola seeds and its defatted meals (Aluko, 2001). Each of these researchers reported that the respective protein concentrates/isolates had valuable functional properties and that these sources of protein concentrates or isolates could potentially offer a wide range of food product applications. In spite of this, limited research is available demonstrating any product development with such protein concentrates/isolates.

Due to the high beta-glucan content of hull-less barley (HB) and demonstrated health implications of this soluble fiber in hypercholesterolemia (Bhatty, 1992; Wang and others, 1992; Newman and others, 1992; Ikegami and others1996; Hecker and others 1998) and hyperglycemia (Pick, 1996; Gosain, 1996; Yokoyama and others, 1997; Pick

and others 1998; Wood and others 2000) interest in the utilization of HB in the food industry has been growing. HB fractionation to obtain beta-glucan concentrate results in a under utilized protein concentrate fraction as a by-product, which has been demonstrated to have key functional properties (Lekhi, 2004). Despite this, there are no reports on the use of barley protein concentrates in food applications or in baked products. On the other hand, the use of high protein foods and the branded low-carb market segment has grown from $0.3 billion to $1.1 billion in the 2003-2004 period (Sloan, 2004) with minimal research on cereal-based protein formulations.

For new food products to succeed in the market place, they must possess adequate sensory appeal and compete with existing standards in the market place. Nutrition conscious consumers and regulations of health claims set the scene for research into consumers' perception of "healthiness" of functional foods and acceptability of such products. The majority (61%) of adults surveyed indicated they always try to check the nutrition label for the fat content of foods they buy (CCC, 2004). Bus and Worsley (2003) investigated consumers' health perception of three types of milk (whole, reduced fat, soy) and reported major differences in shoppers' perceptions among the various types of milk. Richardson and others (1999) found that there were perceptual links between health claim statements on food package labels and those recognized by nutrition experts. Wansink and Park (2002) assessed food labels to determine if the presence or absence of a health claim and/or soy ingredient biased taste perceptions. They found that the presence of soy ingredient together with a health claim made the health claim believable, but in doing so negatively influenced taste perception. Consumer attitudes and

acceptability of soy-fortified yogurts were studied by Drake and Gerard (2003) who found that the knowledge of a health claim increased the acceptability scores for the yogurts.

Research on the use of cereal-based proteins in baked products has been limited. As well, the literature lacks information on consumers' acceptability of such products. Therefore, the overall objective of this study was to compare cookie formulations made with concentrated protein ingredients of barley, oat, and soy. Based on the previous consumer testing of cookies made with concentrated barley protein (Chapter 3) a substitution level of 20% was selected to carry out further consumer testing. The specific objectives were:

1. to evaluate the physical properties of cookies fortified with concentrated protein ingredients (barley, oat, and soy),
2. to evaluate the consumer acceptability of cookies fortified with concentrated protein ingredients (barley, oat, soy), and
3. to evaluate consumer response to nutrition information about the concentrated protein ingredients.

4.2. Materials and Methods

4.2.1. Materials

CDC Candle barley (500 kg), hull-less waxy type, was provided by Agricore United (Calgary, AB), which was pearled to 19% (Temelli and others, 2000) and used as

the starting material for alkali extraction according to Lekhi (2004). The barley protein extraction was completed prior to the commencement of this study and 12 kg of concentrated barley protein (32% protein content) was obtained. The concentrated oat protein (40%, w/w protein) from Hi-fi oat variety was obtained from Cevena Bioproducts Inc. (Edmonton, AB). Soy protein concentrate (74%, w/w protein) was generously provided by Newlyweds Foods Inc. (Edmonton, AB).

All baking materials were purchased locally at retail grocers in Edmonton, AB as follows: all purpose flour (Canada Safeway, Calgary, AB), Roger's white granulated sugar (Vancouver, BC), Crisco shortening (J.M. Smucker Toronto, ON), Canola Harvest margarine (Canbra Foods Ltd., Lethbridge, AB), eggs Lucerne medium (Canada Safeway, Calgary, AB), vanilla Club House (McCormick, London, ON), Sifto iodized table salt (Mississauga, ON), and baking soda (Canada Safeway, Calgary, AB).

4.2.2. Proximate analysis

Moisture and ash contents were determined using AACC methods 44-19 and 08-01, respectively (AACC, 1981). Lipid content was determined according to AOAC method 24.005 (AOAC, 1999). Protein content of concentrated protein ingredients (barley, oat, and soy) was determined (% N x 6.25) using a nitrogen analyzer (Model FP 428, Leco Corp., St. Joseph, MI). Beta-glucan and starch determinations were done according to McCleary and Glennie-Holmes (1985) and McCleary and others (1994) respectively, using Megazyme assay kits (Megazyme, Inc. Wicklow, Ireland). All analyses of concentrated protein ingredients and cookies were carried out in duplicate.

4.2.3. Preparation of cookies

Concentrated protein ingredients (barley, oat, and soy) were incorporated at 20% (w/w) substitution for all purpose flour (Molt, 2001). This level of substitution was selected based on the finding of the previous study (Chapter 3).Wheat flour control was not included in the experimental design because physical characteristics of wheat control were evaluated in a previous study (Chapter 3), which also provided valuable consumer opinion of cookies fortified with concentrated barley protein. Therefore, in the current study the purpose was to compare cookies prepared with concentrated barley protein to those of oat and soy. Straight percentage by flour weight was used to replace wheat flour with barley, oat, and soy protein fractions at a level of 20%. Cookie formulations are presented in Table 4.1.

Table 4.1 Cookie treatment formulations

	Barley	Oat	Soy
Protein (g)	45.5	45.5	45.5
Flour (g)	181.6	181.6	181.6
Margarine (g)	114	114	114
Crisco (g)	100	100	100
Sugar (g)	152	152	152
Salt (g)	0.5	0.5	0.5
Baking soda (g)	1.8	1.8	1.8
Vanilla (g)	4.7	4.7	4.7
Egg	2	2	2

The cookie preparation method incorporated the cream procedure as shown previously in Figure 3.1 and the method is described in detail in Chapter 3 (section 3.2.3). The only difference was the fixed amount of concentrated protein ingredient used (45.5 g) in this study and the fact that concentrated oat and soy proteins were also used for comparison to concentrated barley protein.

Four batches of cookies containing each of concentrated barley, oat, and soy proteins at 20% (w/w) substitution were prepared for consumer testing. Cookies were baked the day prior to each of the four days of consumer testing and cookies were held at room temperature in plastic bags.

4.2.4. Characterization of physical properties

4.2.4.1. Water binding capacity

The water binding capacity (WBC) of each concentrated protein ingredient was determined according to a modified method of Auffret and others (1994). Approximately 1 g sample was weighed into a 25 mL test tube. Then, 10 mL distilled water was added to each tube, stirred with a glass rod and let to sit at room temperature for 10 min. The samples were then centrifuged at 1,200x*g* for 15 min and checked for separation of free water. If any free water was available, then the test was repeated with a decreased amount (1 mL at a time) of distilled water until no free water separated after centrifuging. Results were expressed as g protein concentrate /g water. Analyses were performed in duplicate for each sample.

4.2.4.2. Oil binding capacity

The oil binding capacity (OBC) was determined according to Ang (1991). Two grams of protein concentrate were weighed in duplicate into pre-weighed 50 mL centrifuge tubes. The samples were mixed with 30 g canola oil using a glass rod. The samples were centrifuged at 2,000xg for 15 min. After centrifugation, the supernatant solution was drained and the wet precipitate was weighed. Results were expressed as g oil retained/g sample (Ang, 1991). Analyses were performed in duplicate for each sample.

4.2.4.3. Cookie spread

AACC method 10-50D (1997) was followed for the preparation of cookies used to determine cookie spread. The test cookies had replacement of 20% (w/w) of all purpose flour with concentrated protein ingredient (barley, oat and soy). Modifications made include reduction of baking time from 10 min to 8 min at 200^0C. Wooden gauges (6 mm) and cookie cutter (62 mm) were used to cut cookies for cookie spread testing. Cookie thickness was determined by taking six cookies stacked on top of each other and measuring with fiberglass non-stretching measuring tape. The same six cookies were then stacked upon each other in different order, re-measured and the average for the 2 measurements was reported. The width of cookies was derived by taking the same six cookies and placing them side by side and measuring from end to end, rearranging the order, re-measuring and the average value was reported for the 2 separate measurements.

The cookie spread value is a ratio of width divided by height. All samples were run in duplicate for each of the two replications.

4.2.4.4. Compression tests

4.2.4.4.1. Cookie dough

Compression force was evaluated on raw cookie dough prepared according to cookie spread procedure. A standard cylindrical shape with a diameter of 42 mm and thickness of 20 mm was cut in duplicate from each batch of cookie spread dough. Cookie dough from each treatment was compressed using an Instron Universal Testing Machine (Model 3201, Instron Corp., Canton, MA) longitudinally to 50% of its original height. Compression force (kgF) was recorded as a function of displacement (mm) and maximum force was then taken as a measure of dough strength. Dough compression testing was performed on doughs prepared using 20% substitution with concentrated barley, oat, and soy protein. Data were processed with Instron series IX software (Instron Corp., Canton, MA). All analyses were preformed in duplicate for each of the two replications.

4.2.4.4.2. Whole cookies

Shear force (kgF) was evaluated on whole baked cookies using an Instron Unviversal Testing Machine (Model 3201, Instron Corp., Canton, MA) with a 5 kg load cell. Cookies were baked, cooled on wire racks for 2 h and stored in plastic bags for 24 h before testing. Samples were placed on the platform and cut completely through with a

stainless steel blade at a crosshead speed of 100 mm/min at a set distance of 25 cm. Shear force (kgF) was recorded and the maximum force was taken as a measure of hardness for whole cookie samples. Shear force was recorded for whole baked cookies prepared using 20% substitution with concentrated barley, oat, and soy protein. Data were processed with Instron series IX software (Instron Corp., Canton, MA). All analyses were carried out in duplicate for each day of cookie preparation.

4.2.4.5. Colour determination

A Hunterlab (Labscan Spectrocolorimeter) LAB-XE Colour Difference Meter (Hunter Associates Laboratory Inc., Reston, VA) was utilized to measure colour differences among all three cookie formulations for each testing day. Six samples of each treatment were randomly selected from each baking day, held for approximately 24 h and triplicate readings were taken on each cookie by rotating it 120^0 three times. Results were expressed in "L" (0=black, 100=white), "a" (- =green, + =red) and "b" (- =blue, + =yellow) values. Calibration of the instrument was performed using a white tile with known values of "L" (91.66), "a" (-1.00) and "b" (-0.02).

4.2.4.6. Sensory evaluation

A consumer testing protocol was approved by the Human Research Ethics Board of the Faculty of Agriculture, Forestry, and Home Economics. Criteria to participate in the study included being 18 years of age or older, and cognitively able to participate with adequate literacy skills, and having no sensitivities, intolerances, or allergies to cookie

ingredients (vegetable shortening, margarine, eggs, vanilla, wheat flour, baking soda, white sugar), barley, oat, soy, or club soda.

Cookies were prepared and baked as outlined above the day prior to consumer testing. A total of 4 consecutive consumer tests were conducted at various locations on the University of Alberta campus (Edmonton, AB). Cookie treatments were evaluated using standard consumer sensory testing procedures (Meilgaard and others, 1999) by 350 consumers. Informed consent was collected prior to evaluations.

Consumers were asked to sample two sets of cookies, the first set of samples was sampled blind (labeled Group 1) and placed on a 22.5cm Styrofoam plate that was divided into three sections labeled with three digit sample codes following randomized presentation. A sample scorecard is provided in Appendix 5. Consumers were provided with club soda to cleanse their palates before testing and between samples. Consumers were asked to complete a brief demographic questionnaire at the completion of the first set of cookie samples (Appendix 6). After completing the demographic questionnaire, consumers were presented with the second set of samples which were placed on a 22.5 cm Styrofoam plate that was divided into three sections and labeled with the corresponding protein type (barley, oat, soy). The consumers were divided into two groups, one receiving specific nutrition information labeled as Group 2, while the other group was given general nutrition information and labeled as Group 3. The actual ballots presented to Groups 2 and 3 are shown in Appendix 7 and Appendix 8. The specific information provided to Group 2 was as follows:

Soy:

According to Food and Drug Administration (FDA) in the United States, diets low in saturated fat and cholesterol that include 25 grams of soy protein a day may reduce the risk of heart disease.

These cookies contain approximately 3.9 grams of soy protein/serving

(~6 cookies/serving)

Oat:

Cereal based proteins especially from oats may be part of a healthy diet low in saturated fat and cholesterol.

These cookies contain approximately 2.5 grams of oat protein/serving.

(~6 cookies/serving)

Barley:

Cereal based proteins especially from barley may be part of a healthy diet low in saturated fat and cholesterol.

These cookies contain approximately 2.5 grams of barley protein/serving.

(~6 cookies/serving)

The general information provided to Group 3 was as follows:

Soy:

These cookies contain approximately 3.9 grams of soy protein/serving.

(~6 cookies/serving)

Oat:

These cookies contain approximately 2.5 grams of oat protein/serving.

(~6 cookies/serving)

Barley:

These cookies contain approximately 2.5 grams of barley protein/serving.

(~6 cookies/serving)

Consumers were given scorecards (Appendix 9) to evaluate three randomized balanced samples (one from each type of concentrated protein) for appearance, aroma, texture, flavour, and overall acceptability using a 9 point hedonic scale (1= dislike extremely appearance, aroma, texture, flavour, overall acceptability to 9= like extremely appearance, aroma, texture, flavour, overall acceptability). After completing both sets of samples, consumers were offered a sweet treat for their participation.

4.2.4.7. Statistical analysis

Analysis of variance for proximate analysis, Instron measurements, cookie spread, and Hunter colour was completed using the General Linear Model procedure of SPSS Statistical Software, Version 13.0.1. (SPSS Institute, Inc. 2000). Multiple comparison of means was performed by Tukey's studentized range (HSD) test at α=0.05 level.

To perform analysis of variance of sensory evaluation results a complete randomized design was used. The model consisted of the main effects of Groups 1, 2, and 3, and protein type (barley, oat, and soy) as well as their interaction effects. Multiple comparison of means were performed by Tukey's studentized range (HSD) test at α=0.05 level.

4.3. Results and Discussion

4.3.1. Proximate analysis

Proximate analysis results for barley, oat, and soy concentrated proteins used in this study are presented in Table 4.2. Protein content of the concentrated barley protein (32.4%) obtained at pilot plant scale was substantially lower than that obtained by Lehki (2004) in the laboratory scale who reported highest purity of 70-82% and the recovery of 66-74% for 19% pearled grain flour of CDC Candle with NaOH at pH 11 and 23°C. Low purity is attributed to the lower separation efficiency of the decanter centrifuge used at the pilot plant compared to the laboratory centrifuge. Low yields were mainly attributed to processing difficulties with the decanter centrifuge and large losses in spray drying of the final material. Wu (1979) recovered 51-72% of total barley proteins with protein content between 72-84% from an alkaline extraction procedure using hull-less high protein barley varieties. Hettiarachchy (1996) reported a 90% protein isolate from defatted wheat germ with alkaline extraction. Aluko and McIntosh (2001) reported that protein content of defatted canola seed meals obtained at pH 7.0 ranged from 32% – 78% whereas the acid precipitated protein isolates from defatted canola seed meals ranged from 76% to 79% protein. Beta-glucan concentration was significantly ($p \leq 0.05$) higher in barley compared to oat or soy concentrated proteins. Beta-glucan content of 8.55% (w/w) may have been decreased if the extraction temperature was increased to 50^0C as reported by Lekhi (2004) and Zeng and others (1998). Ash content was higher in barley and soy

compared to oat ($p \leq 0.05$), which is partly due to sodium chloride formed by neutralization following alkali extraction (Wu and others 1979). McGuire (1984) suggested that flour ash content was strongly correlated to cookie diameter.

Table 4.2 Proximate analysis of concentrated barley, oat, and soy protein ingredients [1]

	Barley	Oat	Soy
Protein	32.40 ± 0.05[a]	40.25 ± 0.05[b]	73.53 ± 0.05[c]
Starch/sugars	47.03 ± 0.58[a]	15.20 ± 1.46[b]	16.62 ± 0.58[b]
Beta-glucan	8.55 ± 0.06[a]	1.16 ± 0.09[b]	0.074 ± 0.01[c]
Fat	1.89 ± 0.17[a]	37.17 ± 1.01[b]	0.62 ± 0.09[c]
Moisture	5.76 ± 0.13[a]	3.80 ± 0.19[b]	4.62 ± 0.53[c]
Ash	4.37 ± 0.39[a]	2.43 ± 0.03[b]	4.55 ± 0.00[a]

[1] % w/w as is basis, mean ± standard deviation
[a-c] Means with different letters in a row are significantly different ($p \leq 0.05$).

Fat was significantly ($p \leq 0.05$) different for all three concentrated proteins and was highest for oat at 37.2% compared to 1.9%, and 0.6% for barley and soy, respectively. Oat grain is high in fat content and given that the oat was not defatted prior to fractionation explains why the concentrated oat protein is higher in lipid ($p \leq 0.05$) than barley or soy concentrated proteins. Typically, soy protein concentrate is made from defatted soy flour resulting in minimal fat content in soy concentrates.

4.3.2. Water binding capacity

Concentrated barley and soy proteins were significantly ($p \leq 0.05$) different

compared to oat in terms of WBC as shown in Table 4.3. Soy protein concentrate absorbed the largest amount of water followed by barley and oat was a mere 70% of barley and 75% of soy for WBC. Cookies formulated with concentrated oat protein may produce superior cookies due to the fact that flours with low water-retention capacity are better for baking (Slade and Levine, 1994).

Table 4.3 Water binding capacity of concentrated proteins

Type of Protein	Weight of Protein (g): Weight of Water (g)
Barley	1 : 5.0[a]
Oat	1 : 1.5[b]
Soy	1 : 6.0 [a]

[a-b] Means with different letters are significantly different ($p \leq 0.05$).

McWatters (1978) reported that soybean flour at 20% and 30% replacement of wheat flour restricted cookie spread due to the high water-absorptive properties. They also reported that soybean flour dough was drier and more crumbly, which is in agreement with the current study. Ma (1983) determined WBC of alkali extracted oat protein concentrates to be 0.8 g water /g protein, which is slightly lower than that obtained in this study. Lekhi (2004) found CDC Candle protein concentrate hydration capacity to be 4.28 g water/g protein, which correlates well to the present finding of 5 g water/g protein. Wu and others (1979) reported slightly lower hydration capacity for high-protein high-lysine barley varieties. Overall, concentrated barley proteins may have a higher hydration capacity than other cereal protein concentrates and similar to that of oilseed protein concentrates. In the current study, the concentrated barley protein also has a high content of beta-glucan, which is very hydrophilic consequently increasing WBC. Higher WBC

contributes to moistness of baked products and is attributed to the soft type of cookie produced. The barley cookies were soft type, which could be attributed to the higher WBC; however, the soy cookies were not as soft as the barley cookies but had similar WBC. The difference in softness may be due to the presence of beta-glucan as the oat cookies with the smallest WBC were still a soft type cookie. Satisfactory WBC of concentrated barley protein could suggest its use as a water-binding agent in various food products (Wu and others, 1979) and should be useful as a functional agent in bakery products (Giami and Barber 2004).

4.3.3. Oil binding capacity

Table 4.4 shows the oil binding capacity (OBC) of the concentrated protein ingredients used in this study. The OBC was found to be the highest in oat probably due to the higher fat content of the oat protein concentrate. This finding agrees with Akubor (2004) who evaluated OBC of various types of wheat flour, African breadfruit kernel flour and their blends and reported that the higher the fat content of the flours the higher the OBC. Due to the ability to bind fat and form stable emulsions in an oil-water system (Lekhi, 2004) barley protein concentrates would be suitable as surfactants.

Table 4.4 Oil binding capacity of concentrated proteins

Type of Flour	Weight of Flour (g) : weight of Oil (g)
Barley	1 : 1.87 [b]
Oat	1 : 1.03 [a]
Soy	1 : 1.95 [b]

[a-b] Means with different letters are significantly different ($p \leq 0.05$).

4.3.4. Compression test

4.3.4.1. Cookie dough

No significant difference between replications was found indicating that Instron measurements were reproducible even though soy dough was difficult to handle as compared to the other doughs. Figure 4.1 graphically displays compression force vs displacement curves for doughs prepared with 20% (w/w) substitution with concentrated barley, oat, and soy proteins and

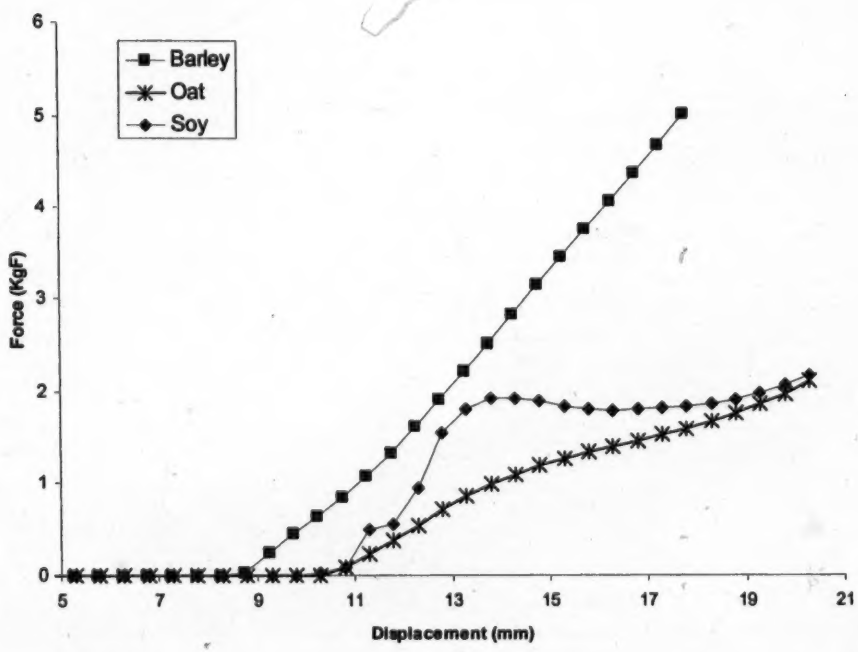

Figure 4.1 Representative compression force vs. displacement curves for cookie dough prepared with 20% barley, oat, and soy concentrated protein ingredients.

Table 4.5 presents numerical values for maximum force. Barley was significantly ($p \leq 0.05$) different from oat and soy for 50% dough compression requiring the highest force. Cookie dough is cohesive, but lacks the viscoelasticity of bread dough due to the poor gluten network. However, this study found that the barley dough did form a strong network as it required nearly twice as much force to compress than that of oat and nearly three times as much as that of soy. Figure 4.2 shows photographs of cookie doughs before and after compression. The barley dough not only held its shape and size, but seemed to recover its shape or "spring" (Jowit, 1974) back to its near original height following compression and demonstrates the cohesiveness of the barley dough. The high level of beta-glucan in the current concentrated barley protein may have contributed to this cohesive structure as well. The oat remained deformed or "plastic" (Jowitt, 1974) and the soy dough was crumbly and difficult to handle.

Table 4.5 Maximum force measurements[1] on barley, oat, and soy cookie doughs

Maximum Force	(kgF)
Barley	4.89[a]
Oat	2.68[b]
Soy	1.76[c]

[1]All measurements were performed in duplicate.
[a-c] Means with different letters are significantly different ($p \leq 0.05$).

a) before dough compression, barley (left) and soy (right)

b) after dough compression; oat (top left) barley (top right), soy (bottom right)

Figure 4.2 Photograph of cookie doughs with 20% substitution with barley, oat and soy concentrated protein ingredients before and after compression.

4.3.4.2. Whole cookie

Barley required the greatest amount of force to cut the whole cookie as revealed in the graph of shear force vs displacement in Figure 4.3.

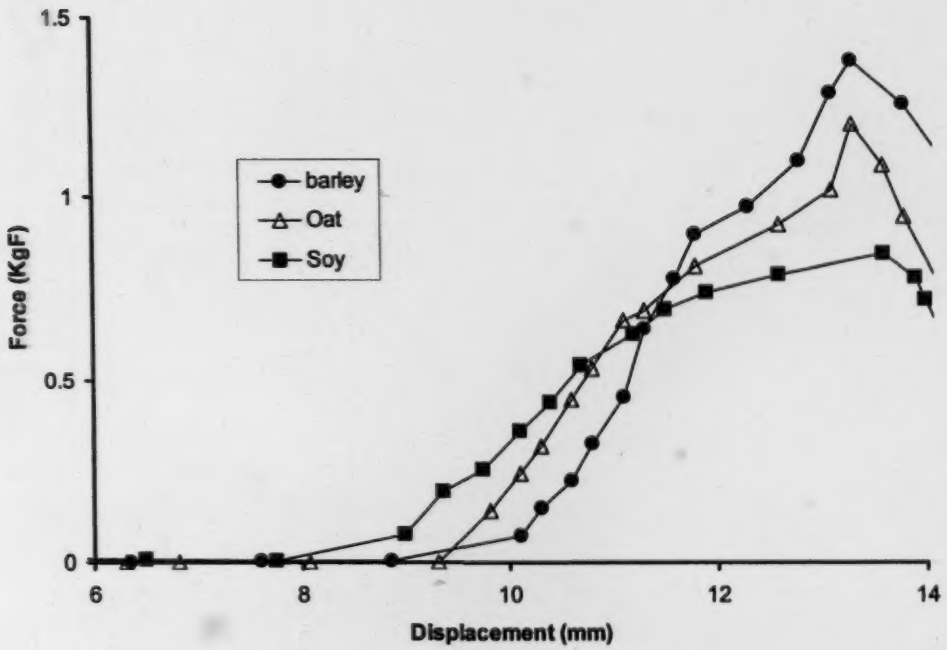

Figure 4.3 Representative shear force vs. displacement curves for cookies prepared with 20% barley, oat, and soy concentrated protein ingredients.

The greater the force (kgF) the harder and less tender is the cookie. This study is not in agreement with Newman and others (1990) who reported higher tenderness of barley muffins made with barley flour and bran. Swanson and Penfield (1982) also reported higher tenderness of quick bread containing barley flour. Peak force is an indication of certain textural characteristics of each type of cookie. Peak force is the maximum resistance of each cookie against the cutting blade, thus the samples with high peak force are less tender. There was a significant ($p \leq 0.05$) difference between barley compared to oat and soy cookies at 20% (w/w) substitution while oat and soy were similar ($p > 0.05$) as shown in Table 4.6.

Table 4.6 Maximum force for 20% whole cookies prepared with barley, oat, and soy concentrated proteins

Treatment	Maximum Force (kgF)
Barley	1.33[a]
Oat	1.14[b]
Soy	1.17[b]
SEM[1]	0.052

[a-b] Means with different letters are significantly different ($p \leq 0.05$)
[1] Standard error of the mean

4.3.5. Cookie spread

The spread value for 20% substitution for all concentrated proteins (barley, oat, and soy) is significantly ($p \leq 0.05$) different as shown in Table 4.7. Barley has the smallest spread factor followed by soy both of which have high WBC as previously discussed in section 4.3.2. Oat has the highest spread factor and the lowest WBC, which is in agreement with Yamazaki (1962) who reported that flours with low hydration properties produced cookies with greater spread. Thus, it can be concluded that oat protein concentrate with low water binding capacity produced cookies with better cookie parameters. Concentrated barley and soy proteins with high water binding capacity will cause reduced dough elasticity as shown with decreased diameter. The spread is caused by the viscosity of the dough and by the expansion of dough through leavening (Wu and others 2003). Fuhr (1962) suggested that competition among ingredients for available

water affects the cookie spread. Oat had the highest ($p \leq 0.05$) fat content so as to allow more interaction and increased tenderization effect resulting in better spread.

Table 4.7 Width, thickness and spread factor for cookies prepared with concentrated barley, oat, and soy proteins

Concentrate protein	Width (mm)	Thickness (mm)	Spread (ratio)
Barley	36.4± 0.2[a]	8.0± 0.1[a]	45.2± 0.8[a]
Oat	41.9± 0.1[b]	7.2± 0.2[b]	58.2± 1.9[b]
Soy	36.5± 0.1[a]	7.2± 0.1[b]	51.0± 0.6[c]

Mean values are from duplicate samples from two replicated trials.
[a-c] Means with different letters in each column are significantly different ($p \leq 0.05$).

The height differences measured as part of spread factor between the three types of cookies can be explained by the differences in water and oil binding capacities. The soy cookies did not retain much of the CO_2 causing dough to collapse, which was reflected in significantly ($p \leq 0.05$) different heights, as clearly shown in Figure 4.4. Barley protein cookie at 20% substitution produced the thickest cookies ($p \leq 0.05$) probably due to the high beta-glucan content and strong protein network developed. Zoulias and others (2000) proposed that beta-glucan acts as a secondary source of network formation that exaggerates the gluten network to elastic shrinkage resulting in a smaller diameter. The results of the present study are in agreement with this finding in that the concentrated barley protein has the highest amount of beta-glucan (8.55%) compared to oat (1.6%) and soy (0.07%) and this is the likely reason for the significantly ($p \leq 0.05$) different widths and heights of cookies.

Figure 4.4 Photograph of height differences for 20% substitution cookies with concentrated barley, oat, and soy proteins.

Vital wheat gluten was compared with soy-derived protein concentrates on baking performance of sugar-snap cookies and all these ingredients negatively affected cookie spread but the least effect was seen with vital wheat gluten (Kissell and Yamazaki, 1975). Dough cohesiveness being negatively correlated with spread factor was reported by Gujral (2003), which is in agreement with the present findings that barley dough was more cohesive and elastic and thus resulted in reduced cookie spread. Klamczynski and Czuchajowska (1999) also reported smaller diameter cookies made with waxy barley compared to non-waxy cultivars. It is important to note that waxy barley proteins have higher beta-glucan content.

The oat cookie was significantly ($p \leq 0.05$) wider with a larger spread ($p \leq 0.05$) compared to barley and soy, which were similar ($p > 0.05$) in width. Figure 4.5 reveals the

difference in widths of barley, oat, and soy cookies. This study is in agreement with Alobo (2001) who reported that an increase in protein content with co-contaminants increase spread factor and it is possible that fat and other functional ingredients may also affect the spread.

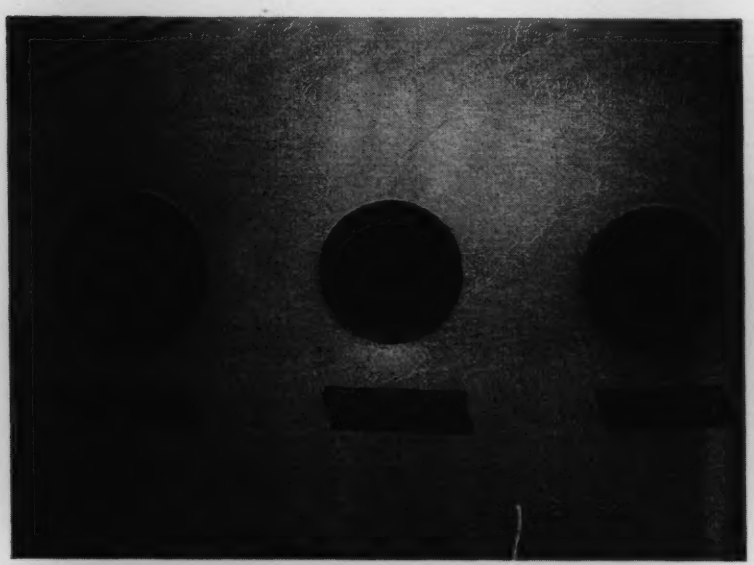

Figure 4.5 Photograph of barley, oat, and soy cookies used in width measurements.

Giami (2004) reported that increasing the level of fluted pumpkin concentrate in cookies significantly decreased the diameter. A pronounced effect was shown with germinated fluted pumpkin seed concentrate, especially at >20% substitution, compared to un-germinated fluted pumpkin seed concentrate. Miller and Hoseney (1997) investigated factors in hard wheat flours responsible for reduced cookie spread and reported that some other factor in addition to protein content was affecting cookie set

time. They found that there was a reasonable correlation between protein content and set time; the higher the protein content in either soft or hard type flours the lower was the set time.

4.3.6. Colour determination

Table 4.8 lists all colour parameters, "L" for lightness, "a" for redness and "b" for yellowness for the three types of cookies. Table 4.8 demonstrates that all concentrates were significantly ($p \leq 0.05$) different in terms of "L" value with barley being the darkest ($p \leq 0.05$) (56.88) compared to oat (59.48) and the lightest being soy (70.69). Barley was also significantly ($p \leq 0.05$) different in terms of "a" value (3.52) whereas barley and oat were similar ($p > 0.05$) in terms of "b" value (15.96 and 15.79, respectively) compared to soy, which was significantly ($p \leq 0.05$) different (19.08) and definitely the most yellow of the three samples. Colour is often the first attribute consumers encounter and is an important consideration especially when developing new products.

Table 4.8. Hunter colour values for whole cookies prepared with concentrated barley, oat, and soy proteins

	L[1]	a[2]	b[3]
Barley	56.88[a]	3.52[a]	15.96[a]
Oat	59.48[b]	1.57[b]	15.79[a]
Soy	70.69[c]	0.29[c]	19.08[b]
SEM[4]	0.74	0.12	0.49

[a–c] Means in the same column with different letters are significantly ($p \leq 0.05$) different.
[1]L = lightness to darkness value (100 white, 0 black)
[2]a = red to green values (+ red, - green)
[3]b = yellow to blue value (+yellow, - blue)
[4]SEM = Standard error of the mean

4.3.7. Sensory evaluation

Table 4.9 lists the mean results from the consumer panel evaluating appearance, aroma, flavour, texture, and overall acceptability of cookies prepared with the three concentrated protein ingredients. Oat is significantly ($p \leq 0.05$) better than barley and soy for appearance, aroma, flavour and overall acceptability. From a practical point of view consumers evaluation of overall acceptability was "like moderately" for oats and "like slightly for barley and soy. In a previous study (Chapter 3), principle components analysis demonstrated that sweetness had a significant impact on overall opinion. In this study, the consumer panel was not asked to evaluate sweetness specifically, but they would have dumped the impact of sweetness into their overall evaluation. There was no significant ($p > 0.05$) effect of nutrition information between Groups 1, 2, and 3 except for the attribute of aroma. Group 1 was significantly ($p \leq 0.05$) lower in terms of aroma compared to that of Group 2 and Group 3, who received specific and general nutrition information respectively.

Table 4.9 Concentrated protein barley, oat, and soy and significant interaction

	Appearance	Aroma	Flavour	Texture	Overall
Barley	6.1^{b}	5.80^{b}	6.0^{b}	6.4^{a}	6.0^{b}
Oat	6.3^{a}	6.5^{a}	6.5^{a}	6.4^{b}	6.5^{a}
Soy	6.2^{b}	5.9^{b}	6.1^{b}	6.3^{c}	6.1^{b}
SEM[1]	0.06	0.06	0.27	0.07	0.07

[a-c] Means with different letters in the same column are significantly ($p \leq 0.05$) different.
[1] Standard error of the mean.

There was a significant interaction effect of treatment x group for the attributes of aroma, flavour, and overall acceptability. Table 4.10 displays the mean hedonic scores for each treatment and group combination. There was a significant ($p \leq 0.05$) increase in flavour and overall acceptability scores for barley with Group 3 (general nutrition information). Even though statistically there was a significant ($p \leq 0.05$) increase from a practical point of view the hedonic scores for all barley Groups (1, 2, and 3) are "like slightly" for flavour and overall acceptability indicating that providing general nutrition information did not have an effect. Oat had a significant ($p \leq 0.05$) decrease for the attributes aroma (Group 1 and 2), flavour (Group 3), and overall acceptability (Group 3). From a practical perspective oat changed from "like moderately (7) to "like slightly" in aroma for both Groups 2 and 3, whereas flavour and overall acceptability decreased from "like moderately (7) to "like slightly" (6) for Group 3, thus indicating a clear decrease in liking with general nutrition information. Providing nutrition information had no effect on soy proteins with overall acceptability at "like slightly". The difference in the wording of the specific nutrition information (Group 2) between soy, which has an FDA approved health claim and that of barley and oat concentrated proteins may have confused the consumer panel. Whereas, the general nutrition information (Group3) was identical wording for each concentrated protein ingredient (barley, oat, and soy) and may have been interpreted by consumers clearer.

Table 4.10 Concentrated protein (barley, oat, and soy) x Group 1, 2, and 3 significant interaction effect

Treatment	Group	Appearance	Aroma	Flavour	Texture	Overall
Barley	1	6.0±1.5	5.7±1.5[a]	5.7±2.1[a]	6.1±1.8	5.8±2.0[a]
	2	6.0±1.4	5.7±1.4[a]	5.8±1.9[a]	6.0±1.6	5.8±1.9[a]
	3	6.2±1.5	6.0±1.5[a]	6.3±1.9[b]	6.4±1.6	6.4±1.8[b]
Oat	1	6.2±1.5	6.9±1.4[l]	6.8±1.5[l]	6.6±1.6	6.7±1.4[l]
	2	6.3±1.3	6.4±1.2[m]	6.6±1.4[l]	6.4±1.4	6.5±1.4[l]
	3	6.3±1.3	6.1±1.4[m]	6.1±1.8[m]	6.3±1.4	6.2±1.7[m]
Soy	1	6.1±1.6	6.0±1.4[r]	6.2±1.9[r]	6.4±1.6	6.2±1.8[r]
	2	6.2±1.3	5.9±1.4[r]	5.9±2.0[r]	6.1±1.6	5.9±1.8[r]
	3	6.2±1.5	6.0±1.5[r]	6.1±1.9[r]	6.3±1.5	6.1±1.8[r]

[a-b] Means for barley with the same letter in the same column are not significantly ($p>0.05$) different.
[l-m] Means for oat with the same letter in the same column are not significantly ($p>0.05$) different.
[r] Means for soy with the same letter in the same column are not significantly ($p>0.05$) different.

Pelletier and others (2002) looked at the effects of an educational program on intent to consume functional foods and found that only 10% of the participants consumed oats daily, which was surprising to researchers given that the oat health claim was approved in 1997. However, after the education program 77% intended to increase oat consumption. These researchers also reported that only 20% of their participants consumed soy weekly whereas the United Soybean Board survey (2002) revealed 25% reported eating soy weekly and 42% reported awareness of soy health claim. According to the National Marketing Institute (2003) consumers are looking for a positive health benefit and claims on food labels (Sloan, 2003). Soy cookies were evaluated similarly ($p>0.05$) for all the attributes (appearance, aroma, flavour, texture, and overall

acceptability) tested in this study regardless of the type of nutrition information. Wansink and Park (2002) found that having a soy label negatively influenced taste perception, whereas the current study found no effect with soy labeled cookies. Drake and Gerard (2003) reported that knowledge of health claim increased acceptability scores for yogurts with or without soy and the current study found that general nutrition information increased barley overall acceptability, whereas oat liking decreased while soy was not affected.

The prevalent age group for the consumer panel was between the ages of 20-30 years old and nearly 75% of the consumer group was females. Over 75% of consumers who participated in this study indicated that they do read nutrition information (Figure 4.6). Pelletier and others (2002) reported that 65% of subjects between the ages of 18 to 35 reported less importance on health claims or nutrition information. Therefore, the current study might be more of a reflection of this age group. A higher percentage of females than males reported reading nutrition information, 76% vs 25%, respectively. Other researchers (ADA, 2002) have also reported females having higher interest in nutrition information.

Over 75% of the consumers indicated consuming cookies between once a week and several times a month (Figure 4.7). Calorie Control Survey conducted in 1998 found that 72% of reduced-fat food and beverage consumers reported using these products at least several times a week and 48% used these products daily (CCC, 2000). Urala and others (2003) reported an advantage of using health claims when the health claim was attached to a food product that was used daily. Therefore, it could be advantageous for

the bakery product and cookie manufactures to use functional ingredients like concentrated barley protein in their products and identify them with an appropriate form of claim on their package labeling.

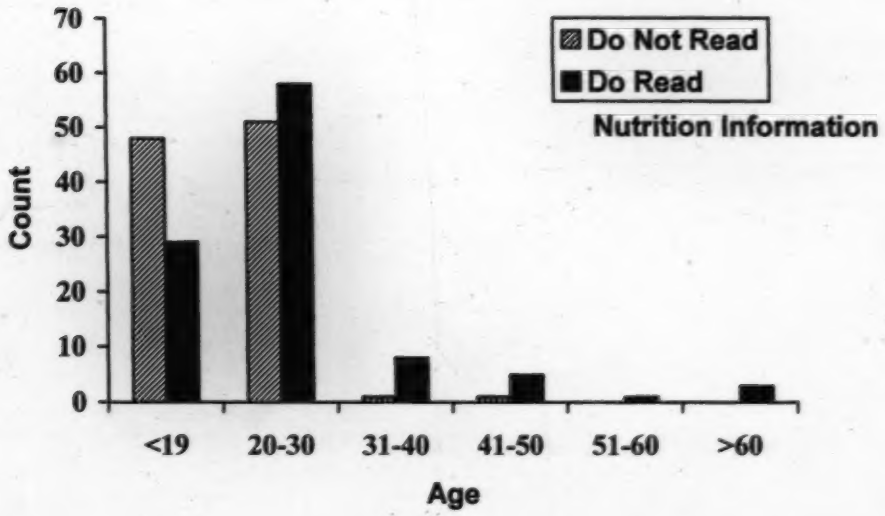

Figure 4.6 Frequency of consumer who do read and do not read nutrition information and corresponding age groups

Figure 4.7 Pie chart of consumer's rating of consumption of cookies (OW=once/week, SM=several/month SW=several times/week, D=daily, NE=never eaten, OM=once/month).

4.4. Conclusions

Protein-enriched cookies prepared with concentrated barley, oat, and soy proteins at 20% substitution level were significantly ($p \leq 0.05$) different in terms of the physical properties investigated. The barley cookie had a reduced spread and higher maximum f shear force and higher dough compression force than oat or soy cookies. There was a significant ($p \leq 0.05$) difference in colour for lightness and redness among the three cookies. The consumer testing revealed that concentrated oat protein cookie had the highest overall acceptability "like moderately" (7) for any group and treatment. Barley and soy concentrated protein cookies rated "like slightly" (6) for all attributes

(appearance, aroma, flavour, texture, and overall acceptability) regardless of group; therefore, nutrition information had no direct effect on hedonic scoring for this consumer population for barley or soy, but a decrease in hedonic liking for concentrated oat protein cookie from "like moderately" to "like slightly" for Group 3 (general nutrition information) for aroma, flavour and overall acceptability. Nearly 75% of the population were females and the predominant age group was 20-30 years of age. Close to 75% of this population indicated they do read nutrition information.

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5. CONCLUSIONS AND RECOMMENDATIONS

Recent progress in understanding the health benefits of beta-glucan, a soluble fibre component abundant in barley and oats, has led to the development of grain fractionation technologies to separate barley into high value components including: starch, beta-glucan, lipid, and protein fractions. Currently, the protein-rich fraction is not being utilized or it is blended into animal feed. Given the current market trends with high-protein foods coupled with growing interest in maintaining health through functional foods, barley protein concentrate could be utilized as a functional ingredient to meet these consumers needs. Cookie, a popular convenient snack food with appeal to a wide range of ages is often considered an indulgent type food and not considered as nutritious. The use of functional ingredients like barley protein concentrate could provide increased nutritional benefits to baked products like cookies.

Sugar cookies were prepared with 0-45% (w/w) substitution of flour with concentrated barley protein. The protein content of all cookies at all substitution levels were higher ($p \leq 0.05$) than that of the control cookie. The beta-glucan content was also significantly ($p \leq 0.05$) higher in all treatments compared to the control due to the high level of beta-glucan in the concentrated barley protein used in this study. Further optimization of the protein extraction process at the pilot plant level is needed to increase the protein concentration of this fraction to >70%, which is the typical level for other protein concentrate ingredients.

Compression testing of cookie dough indicated that any amount of barley protein substitution increased dough strength. Even though the cookie formulation used for compression testing and spread measurements was different from that used for sensory testing, this finding should apply to both. The increase in dough strength is reflective of the enhanced protein network with beta-glucan also contributing to this network. The maximum force to compress cookie dough to 50% of its original height was similar ($p>0.05$) for doughs prepared at 15, 25, and 45% substitution levels. The shear force required to break the baked cookie increased with the level of substitution of concentrated barley protein. The increases in protein content along with the beta-glucan are both responsible for the increased cookie hardness.

Cookie spread was decreased for cookies prepared with concentrated barley protein at any substitution level; however, the 15% treatment had the smallest spread with the largest height. At this level, there is sufficient water in the formulation to hydrate the protein. The glass transition temperature presumably decreased at this protein substitution level resulting in an earlier set time, consequently leading to reduced spread. Increasing protein substitution increases the competition for the same amount of water; therefore, a weaker protein network is formed as less protein is being hydrated. When there is not sufficient water, the extent of starch gelatinization is diminished, which results in a softer type cookie, especially at the higher substitution levels (40 and 45%). The presence of a higher amount of beta-glucan at the higher substitution levels also contributes to a softer type cookie.

Trained sensory panel found that as the percentage substitution of concentrated barley protein increased so did the intensities of cereal aroma, saltiness, cereal flavour, chewiness, cohesiveness, toothpack, and mouthcoat, while sweetness was the only attribute that was inversely affected. The increase in perceived saltiness could be due to the presence of residual salts in the concentrated barley protein and any improvement in protein concentrate purity may reduce the saltiness of the final product. Toothpack and mouthcoat are more than likely attributed to the amount of beta-glucan present as beta-glucan may increase mouthcoat. Chewiness was positively correlated to maximum force and thickness. Toothpack was correlated to thickness and spread. Consumer testing indicated that both 15% and 20% (w/w) substitution treatments were similar to control cookie with an overall opinion of "like moderately".

Based on these results 20% (w/w) substitution was selected to conduct further physical and consumer testing. Concentrated barley protein was compared to oat and soy concentrated proteins. Compression testing of cookie dough prepared at 20% (w/w) substitution with concentrated barley, oat, and soy proteins revealed that the barley dough was significantly ($p \leq 0.05$) higher in terms of maximum force compared to the oat or soy doughs. The soy protein concentrate had a higher protein content (72% w/w) compared to barley at 32% (w/w); therefore, the difference in strength must be attributed to the presence other components found within the concentrated barley protein such as beta-glucan. Oat dough was also significantly ($p \leq 0.05$) different from soy in terms of maximum force and the concentrated oat protein also had (1.16%) beta-glucan present.

The maximum force required to break the barley cookie was significantly ($p \leq 0.05$) higher compared to the oat or soy cookies at 20% substitution.

Concentrated barley and soy proteins had similar ($p > 0.05$) water and oil binding capacities, but barley had the smallest ($p \leq 0.05$) spread of the three cookie types. The concentrated oat protein with the lowest water binding capacity resulted in an acceptable spread. The concentrated oat protein had the highest level of fat, which could have contributed to tenderizing the dough to produce more acceptable spread values.

Comparing concentrated barley, oat, and soy proteins in cookies with 20% (w/w) substitution showed that the oat cookies had the highest hedonic scores for all the attributes tested (aroma, appearance, flavour, texture, and overall acceptability). The overall acceptability for blind tasting of barley and soy cookies was"like slightly and that for the oat cookie was "like moderately". Barley overall acceptability and flavour scores increased significantly ($p \leq 0.05$) with general nutrition information provided to the panelists even though this difference was not significant from a practical point of view. However, the overall acceptability for oat cookies decreased with general nutrition information while nutrition information had no effect on the acceptability of soy cookies. There is the possibility that there was some bias and confusion with both the specific and general nutrition information due to the fact that soy is the only protein concentrate to have an actual FDA approved health claim, which may have put soy at a disadvantage as the other statements provided to the panelists were only worded in a similar manner to the soy health claim. It would be recommended to make all nutrition information statements similar and have a clause in the consent form telling consumers these are not

approved health claims, but they are being used as "mock" health claims for the purpose of the study only.

The consumer population consisted of 75% females and 65% of the population was below the age of 31. Nearly 75% of the population indicated they do read nutrition information. Given that the demographic information revealed under 20 year olds do not read nutrition information and this was the second largest age group participating in this study; consumer testing at a supermarket rather than university campus may have been a more suitable site to obtain a more diverse age group and more reflective of the importance of nutrition information across the different population age groups.

Concentrated barley protein was successfully incorporated into cookies in this thesis research; however, further research is needed for such products to be successful in the market place. One recommendation for future formulation refinement would be to increase the amount of water. Addition of more water to ensure proper hydration of all components may aid with improved spread. In addition, an emulsifier or surfactant may help condition the dough, which would be more effective in producing acceptable cookie spread. Throughout this thesis research all sets of cookies were prepared and made in small scale batches in a laboratory setting. Scale up and the use of industrial scale equipment will affect these proteins differently. Use of sugar solution along with constant temperature when creaming of fats may provide positive environments for these cereal protein concentrates. The protein network will also be affected by the type of mixing and or sheeting used for cookie production. As well, addition of flavourings or other ingredient like chocolate chips and/or nuts also need further investigation to understand

how they interact with the protein network. The current study found that barley protein cookies at 15-20% substitution had hedonic scores of "like moderately"; therefore, adding ingredients like chocolate chips may mask some of the attributes such as cereal flavour, and saltiness; thus increasing hedonic scores.

Water binding and oil binding are both valuable functional properties that could extend the use of concentrated barley protein into a wider variety of food products. The barley proteins could be used as a fat replacer in baked products or as a binder in meat products.

Conducting a focus group would be beneficial for marketers to understand consumers intent on purchasing a cookie made with concentrated barley protein and what nutrition information they are looking for when purchasing healthier foods with functional ingredients. Information on specific health benefits of barley proteins is lacking. Therefore, animal feeding trials as well as human clinical trials to establish the nutritional value and health benefits of barley proteins are critical to promote barley proteins as a functional ingredient.

Given the fact that the cookie market is approximately 10% of the retail sales, formulating an acceptable product with concentrated barley protein could be profitable and increase the consumption of barley in food products, leading to value-added processes of a grain that is of great importance for Alberta's agri-food industry.

Appendix 1 Screening panelists

Panelist screening questionnaire

Contact information:

Name: _____

Phone number (lab/office): _____

Email: _____

Availability:

1. Are there any weekdays (Monday - Thursday) that you will not be available between November 1 to December 12th?

_____
_____
_____

Health:

1. Do you have any of the following?
   - Dentures _____
   - Diabetes _____
   - Oral or gum disease _____
   - Hypoglycemia _____
   - Food allergies _____
   - Hypertension _____
   - Thyroid condition _____
   - Pregnant _____

2. Do you take any medications which affect your senses, especially taste and smell?

_____

Food Habits:

1. Are you currently on a restricted diet? If yes, please explain.

_____

2. What is (are) your favorite foods? _____

3. What is (are) your least favorite foods? _____

4. What foods do you <u>not</u> eat because of insensitivities, intolerances, allergies or dislikes?

Insensitivities → _____
Intolerances → _____
Allergies → _____

5. How would you rate your ability to distinguish smells and tastes?

	Smell	Taste
Better than average	_____	_____
Average	_____	_____
Worse than average	_____	_____

6. Does anyone in your immediate family work for a food company? _____
_____

7. Does anyone in your immediate family work for an advertising company or a marketing research agency? _____
_____

Flavour Quiz:

1. What are some other foods that taste like yogurt? _____

2. What would you say is the difference between flavour and aroma? _____
_____
_____
_____

3. What would you say is the difference between flavour and texture? _____
_____
_____
_____

Pizza Evaluation

• Imagine you are given a slice or two of freshly baked pizza. Indicate what type of toppings would be on the pizza and what distinctive characteristics you would experience when eating the pizza?

• Pizza toppings:
• Important characteristics of the pizza:

Basic Taste Identification Scorecard

On the tray there are five water solutions; four each of the basic tastes plus one of water.

Please taste the samples in the order indicated. **DO NOT SWALLOW THE SAMPLES.** "Swish" the samples around the mouth, then expectorate into the large coloured cup provided. Identify the taste you experience. Rinse your mouth with water between samples and wait one minute before proceeding to the next sample. Continue testing in the same manner until all samples have been tasted. Record your initial reaction and **DO NOT** go back to retaste or change your answer.

Sample Code	*Identity*

Ranking of Sweetness Intensity

Please evaluate and rank the five samples of sweet solutions in water according to their intensity of sweetness. Rank the samples from least sweet to most sweet.

_____ Least sweet
_____
_____
_____
_____ Most sweet

Generate Descriptors for Cookie Samples

Name: _____ Date: _____

Please sample the three cookies and compare and contrast all samples in terms of texture, flavour, aroma, and appearance.

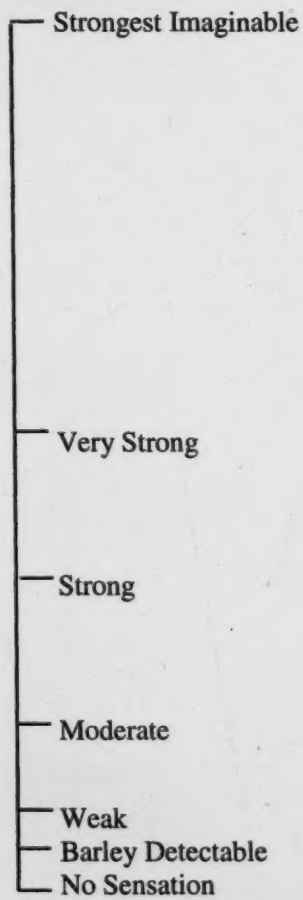
Texture	Flavour	Aroma	Appearance
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

PROP Test Sensation

Name: _____ Date: _____

Instructions:

1. Cleanse your palate with a sip of water
2. Place the PROP solution provided, in your mouth. **DO NOT SWALLOW THE SOLUTION.**
3. Swish it around in your mouth for ***10*** seconds, ***spit out the solution into the cup provided***, then rate the taste of the solution somewhere between no taste at all ***(no sensation)*** and taste which is the strongest sensation that you could imagine having in your mouth ***(strongest imaginable)***.



Appendix 2 Recruitment poster for consumer tasting

Do you like cookies?

Do you like cookies?
Do you eat them at least once a month?

If you do, we have an opportunity for you to try cookies as part of a research study! You'll have the opportunity to taste various types of sugar cookies made with barley protein and tell us what you think!

To register or for more info, call Sandy at (492-3833) sensory@ualberta.ca

Tasting sessions held Dec.2nd & 4th in the Ag.For Centre. Department of Agriculture Food and Nutritional Science

Sandy 492-3833 Cookie Tasting sensory@ualberta.ca
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Sandy 492-3833 Cookie Tasting sensory@ualberta.ca

Appendix 3. Consumer evaluation scorecard and demographic questionnaire.

Cookie Evaluation Scorecard

You have nine coded samples of cookies in front of you. Evaluate the samples in the order shown below.

Please clear your palate before you begin with a sip of club soda.

Sample _____

- **Overall opinion**

Overall, what is your opinion of this cookie?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

If you have any comments on this sample of cookie, please record them below:

_____

_____

_____

Consumer Demographics

Please take a few moments to answer some questions about yourself

1. What is your gender?
   - ❒ Male
   - ❒ Female

2. What is your age range?
   - ❒ Less than 20 years
   - ❒ 20 to 30 years
   - ❒ 31 to 40 years
   - ❒ 41 to 50 years
   - ❒ 51 to 60 years
   - ❒ 61 +

3. Do you consume cookies?
   - ❒ Yes
   - ❒ No

3a. If so, what type of cookie do you consume? (e.g. chocolate chip, oatmeal)

_____
_____
_____

3b. If you do consume cookies, what is the main reason you consume them?

_____
_____
_____

4. How frequently do you consume cookies?
   - ❒ Daily
   - ❒ Several times per week
   - ❒ Once per week
   - ❒ Several times per month
   - ❒ Once per month
   - ❒ Never

Thank you for answering these questions.

Appendix 4. Consumer comments on cookie treatments.

sample %	If you have any comments on this cookie sample %01, please record them below:
0%	very buttery flavor, not the best
0%	tastes just fine...do cookies ever taste truly bad? but this one is far too light and fluffy - no sustance to it
0%	Too sweet. Leaves a metalic aftertaste. Texture great, melts in your mouth and crunchy!
0%	just like mama used to make_
0%	Tastes like the average store bought sugar cookie of childhood. No difference in flavour or texture. Not something I'd eat everyday, but is okay around the holidays.
0%	Very light colour reminds me of traditional sugar cookies. Not very soft, also very cr
0%	the colour of the cookie makes it less appealing. On the sweet side
0%	entirely different than any of the other cookies... i would presume that this one is the control of the test. It is probably the best of the cookies in these four
0%	Very similar to the last sample, had a good testure, and tasted descent.
0%	a little too sweet compared to 259
0%	melt in your mouth delicious_
0%	kinda dry
0%	good consistency
0%	Very nice taste, sweet and i like the texture and how it crumbles in the mouth.
0%	very good flavor, tastes like butter cookies. But it would be better if the texture is a bit more harder instead of so soft. It has a light taste to it and is not heavy.
0%	very sweet and good, much flakier, and not as dense as other samples
0%	Somewhat too sweet for me, but I like it because it seems light and fluffy
0%	Not entirely crazy about this one. It is very crumbly, not chewy enough. It is very sweet too. The shortening in it tastes different to what I'm used to (margarine). It looks nicer, but I think I would eat the other three cookies before this one. It's
0%	It was a good cookie, crunchy, not a strong flavour.
0%	Taste like a normal butter cooky.
0%	quite good.... very similar to those english tea cookies.
0%	my favourite cookie so far; sweet, but that is the way I like it best; no aftertaste, very good texture (light and crispy); a very good cookie
0%	i liked the texture. doesn't sit around in your mouth and turn into mush. color was very different though
0%	148 has much lighter more pleasing apperance. and it tastes just like a regular sugar cookies. this sample in my opinion is much better than the previous samples.
0%	Tasty, just sweet enough!
0%	light and crumbly; kind of like a shortbread cookie, but not as sweet
0%	148 rocked the casbot ... it should be the declared the king of cookies
0%	best one yet. very yummy
0%	Good texture, sort of bland, sickeningly sweet immediate after taste
0%	mmmmmmmmmmmmmmmmmm
0%	This cookie tastes like it has too much butter in it. Although I can't taste the butter, the crunch of the cookie makes me feel like there's too much fat in it. It does have a nice sweet taste though. Maybe a bit TOO sweet.
0%	kinda like shortbread, in BARLEY form!!!!!!!!!!!!!!!!!!!

0% Very nice, however, I think I would like it slightly chewier
0% Very tasty
0% It's nice, it is just a bit too sweet for my taste.
0% it tastes o.k. but too dry. color is too pale but can be acceptable. i expected more chewiness from the cookies.
0% Gross...too dry..horrible aftertaste
0% The cookie is too sweet, and I don't really like the texture.
0% tastes good
0% Very crumbly. Didn't stick to teeth like others. Has a more pleasant appearance when compared to the other 4 cookies. Nice light flavor
0% Tastes really good. Flaky, not hard, but not too crummy. good texture. Clean taste.
0% nice and crispy, pleasant color, nice flavor, nice texture,
0% too sweet and too crispy. Crumbles easily in your mouth
0% it was light in taste, crunchy (crisp), sweeter taste, leaves a good aftertaste in my mouth
0% Tastes like shortbread, but kind of dry.
0% too sweet
0% too crumy
0% I like it in general, just to mention that it was too sweet for me...good color, well made.
0% this cookie was a lot sweeter than the others, but I liked 934 better as it had more substance
0% good for a sugar fix - quite sweet
0% I don't like the texture as much as the preceding samples.
0% tastes like a 'normal' cookie
0% Reminds me of shortbread. I wonder about the fat content.
0% The texture is very good.
0% tastes more traditional--like shortbread
0% buttery
0% Tastes sweeter than 259 and 897- I prefer the others as they seem to have more of a whole grain and less sweet taste
0% the cookie tastes just like a regular shortbread cookie
0% Clearly this cookie used highly processes ingredients. From the previous three samples I had been starting to like the more grainy taste of barley cookies.
0% Nice color, light yellow_Soft ___
0% Oily after taste
0% this cookie was tastier than the first one.
0% Good old fashioned shortbread!
0% crispy and sweeter than the others
0% Does not have much texture or chewyness to it. Melts in your mouth.
0% tastes a lot like shortbread - not as creamy
0% This is definitely a sugar cookie, a little dry. But definitely sugary & buttery
0% It has a nice crumbly texture. I wouldn't eat if I had the choice though because it's too sweet.
0% Pretty good, tastes like shortbread cookies. I like the margarine taste (or butter?).
0% I didn't like or dislike the tast of this cookie, but I really didn't like the texture
0% light and a bit sweet
0% Yummy!
0% very sweet. No barley in here, eh?
0% Too dry

0%	very sweet
0%	this cookie is the sweetest of all but liked the flavor of 463 better
0%	this is a very delicate cookie, similar to shortbread
0%	A sugar cookie, without the sugar. One of the best.
0%	Tastes nice, but quite dry
0%	It looks like the commercial ones
15%	sweeter but less flavor
15%	Texture great - melt in your mouth and crunchy. Good sweetness level. No bad after-taste. Best of the samples thus far!
15%	YUMMY! Dry and crumbly however. Eating this would likely make mess at times. But very tasty. Could make a regular snack of this type of cookie!! Yum! Colour was also appetizing.
15%	a little too sweet
15%	much better than previous two... leaves no aftertaste
15%	Texture was the best so far, and by far the best tasting.
15%	light and sweet
15%	lighter tasting_not so sticky
15%	very sweet
15%	nice flavor, good texture, nice and crunchy. I like it. :)
15%	sweet, crunchy, not too hard...very good_
15%	Nice texture, flavouring is okay too
15%	This is closer to sugar cookies that i've had in the past. It tastes more buttery and it is also sweeter. It is more crumbly than the others, I'm not sure i like that (i hate having crumbs on my lips. chewier or crispier is better. crumbly not so good.
15%	Texture was good, but a slight corn-like after taste is present.
15%	Tastes a lot closer to what I know of as drop sugar cookies.
15%	Crumbly, there is a little lingering taste and a soapy texture on the tongue.
15%	Nice flavour; tastes as I would expect a good sugar cookie to taste.
15%	good texture but strange aftertaste
15%	259 has about the characteristics as 776, but much tastier.
15%	good cookie; not much to say about it though
15%	i could be persuaded to eat a few of those
15%	tastes like a regular sugar cookie
15%	C is for cookie, and this one is good enough for me.
15%	it's no oreo
15%	I really like the texture of this cookie. It had a nice crunch and was sweet. It leaves a pleasant taste in my mouth. I can't resist finishing the sample!
15%	259 was a little better than most, but 148 is still the undisputed barley cookie champion of the universe.
15%	cookie tastes good, still a little bit dry. The colour of the cookie is appealing.
15%	taste good, not too sweet. color is not bad compared to the ones before. Crispiness is right.
15%	Very crisp and not as sticky as the others
15%	It was Ok. but i like the texture and taste of 436 the best_
15%	it's too soft
15%	Very nice texture. The least amount of 'cereal' or barley flavor detected here.
15%	Texture was the best of the 4 so far.
15%	Very good texture. Smooth, light, fresh, flaky, not too crummy.
15%	this was good. nice and crispy, pleasant flavor, not too gummy
15%	good texture, good flavor and not too sweet.

15% Good texture (crunchy)
15% very sweet tasting, light tasting
15% Pretty tasty, more flavour than the last two. Tastes more like a cookie than they did.
15% sweet, soft, good flavor, I really like this one
15% good. very sugary_
15% this was a godd tasting cookie
15% good - has a good level of sweetness
15% not much of any flavour
Sort tastes like 934. A delicious cookie. Actually I would eat any of them. If healthy, I
15% would be inclined to purchase them.
15% the first bite gave me a good impression.
15% sweet taste, nice texture
15% best of the darker cookies
15% Good flavor and texture, tender, slight barley aftertaste which is not unpleasant
this cookie is the closest in taste and texture to a regular shortbread cookie (not
15% exactly like it, but very close)
15% looks ok_
15% Like the texture - smell and taste very much!
15% this cookie was good. and not too dense
15% Very much like 'Whole Wheat' shortbread
15% a slight after taste
15% somewhat dry and crumbly, very buttery flavor
15% Not as chewy as sample 993 but similar to 934 and 897
15% sweet, melts in your mouth
15% This one has more of a sugar cookie taste, but not very heavy/buttery
15% Nice sweet taste. Nice crumbly texture.
15% A little sugar added. Nice.
15% I taste a bit of an aftertaste that I don't really like
15% a touch sweet
15% I like the golden apperance and tastes a little bit sweet.
15% good_
15% I prefer moist cookies, this one was a little dry.
15% this cookie tastes familiar, it has a good taste and sweetness
15% similar taste to digestive cookies, with a texture kind of like peanutbutter cookies
15% nice texture and taste good color
15% The best of all.
15% Seemed to taste like 993 and 897.
15% It looks sweeter
15% its really better than all until now
20% very similar to the last one (625) sweet and soft
20% nice too sweet tasting and slightly crunchy which i like
20%
20% Nice texture and flavour. Second best of samples.
20% sweeter, less fibrous taste
I REALLY like this one! It's dry but tastes really good. More of a dessert style cookie,
more of a treat, but could be eaten every day. Nice and golden brown colour as well.
20% Much like the traditional sugar cookie, but the variation was good. Sweeter tha
20% stronger aftertaste than sample 897
20% Could really taste the barley__

20% nice flavour _generally appealing _
20% sweet
20% tastes similar to shortbread. Good!
20% nice fluffy texture, good flavor, just right.
20% sweeter, not as much aftertaste, flakier
20% I like the flavour, does not stick as much as previous sample
This tastes awesome. It seems like a very 'balanced' cookie. Not too sweet or buttery, but still a very nice texture. I like it the best of the five. 625 is close, and 993
20% if i want to feel like i'm eating a healthy cookie (just add oatmeal!) Still no
20% I perceived an odd flavour
20% Tastes slightly like rice cereal (like the stuff baby's have).
This one is better than 511. I much prefer the texture and taste. Although its more
20% bitter than 148 it has a pleasant aftertaste
20% As with cookie 259, this tasted very good as well.
934 hs the same characteristics as 776, but it apperance is lighter than the previous
20% samples
20% mmm!
20% right down the middle ... like a 7-10 split in bowling
not bad, could be a little crisper. A note for most of the cookies: I tend to think, as a
20% generalization, that the browner the sugar cookie, the less I will likely like it.
20% Yummy._It doesn't even need chocolate chips
20% not bad
I like the sweetness and the texture of this cookie. It has a nice crunch and doesn't
20% leave a bad after taste like some of the others.
If this section of cookies was a boy band, sample 934 would be the old, disgusting
20% band member who hits on underage girls.
20% Good overall.
20% I like the crispinessof the cookie. this one doesn't have after taste.
I really like the color of this cookie. It's a little too crisp for my liking...but that's just
20% my preference. I also think the flavor is really nice
20% crispy
20% more of a sweet flavour with cereal taste afterwards, nice texture!
20% it is okay. Tastes buttery.
20% it sticks in my teeth and leaves a slight greasy feel in my mouth.
this one is a good cookie too (as is 259) it doesn't have too strong of a barley flavor
20% but it is still recognisable.
20% lighter in taste, better taste in my mouth, more sweet tasting
20% Very dry, and lacks flavour.
20% Good flavor, crispy enough, I really like it.
20% good_
20% sweeter than 511 and 463
20% Has a nice flavor to it.
20% lighter texture, sweetness OK, sweet after taste
20% no aftertaste
20% the cookie has a slightly malty or tangy taste. It's a nice texture
I'm guessing that this one had less barley and more flour than previous cookies. As I said earlier, I'm warming up to the barley cookie taste and that makes the flour-
20% containing cookies taste very artificial and refined (as in 'processed').
20% a little dry
20% Good flavour - good crunch - but a little too much baking soda

20% this cookie was lighter. and didn't have the burnt flavour
20% A little salty, initially on the bland side but has a not unpleasant aftertaste
20% i liked the texture and flavour, very little after taste
20% again, gooey when chewed, but flavor is better than 897
20% This one has a slight corn taste too, but is more sugary
20% Tastes great. It tastes light and not too sweet.
20% Tastes just like a plain cookie. Nothing special.
20% not as pastey, sweeter, not as yeasty
20% really liked this cookie probably better than both 140 and 463
20% this one is more buttery than sample 259
20% crumbly and not as sticky
20% Good cookie with pleasant aftertaste._
20% This one had a sweeter aftertaste and seemed to have a less dry texture.
20% it is ok
25% best yet, sweet and not too crumbly
25% yummy_
25% good cookie, good cruchiness factor
25% Sweeter than the other samples, fairly crunchy. Sweeter aftertaste - not as bland as the other samples.
25% Nice and soft and chewy. Very delicious. A smooth flavor leaving the mouth with a pleasant sensation and aftertaste. Would be a great calming snackfood for the end of a work or school day. Not too strong of a flavour, but this would make it more likely
25% smoothe texture, melted in your mouth
25% best one of the first 5
25% Gummy, and had a flowery taste._
25% bit of an aftertaste_tastes like some kind of cereal
25% very yummy. sweeter than 511
25% really bad taste and after taste
25% Overall taste is pretty good it could use a bit more sweetness.
25% good flavor, light and fluffy texture.
25% chewy, sweeter than 897, leaves bland taste in mouth_
25% Nice flavouring and texture
25% I like this one better than 897. The texture is nicer and so is the overall flavour.
25% It is not crispy when I chew it.
25% A corn-like after taste is strongly present, and I did not like it at all.
25% Slight aftertaste, but quite pleasant.
25% Less crumbly, stronger 'burnt' flavour.
25% not as good as previous cookies, but better then others...
25% good texture; mild aftertaste, appropriate sweetness; a fairly good cookie
25% better than the others. The flavour wasn't as strong. but the texture was pleasing
25% tastes like a whole-grain cereal and it loks darker then a regular cookie
25% average cookie
25% if i were to lick a maple tree, i think this is what it would taste like
25% very good
25% nICE TEXTURE, GREAT TASTE.
25% Although the cookie is sweet, it leaves a pasty, floury flavour in my mouth.
25% it's like there's a party in my mouth, and no one was invited.
25% This sample was sweeter than sample 116, however, I preferred the chewiness of

	sample 776, 625 was a bit too dry.
25%	Excellent texture. Flavour a bit off.
25%	i like the crispiness of the cookie. a bit slimy and after taste
25%	this cookie was quite crisp and tasted very similar to a normal sugar cookie
25%	not bad
25%	nice texture and flavour
25%	Tastes fresh, and cruchy. Good taste.
25%	this one was a little more crispy - that's a good thing
25%	this cookie is good. Not quite as strong of a 'grainy' flavor. It is more crisp than 463, 993 or 776
25%	good texture (crunchy)
25%	a little bit more of an aftertaste but still tasted good, good crunch, light texture and taste
25%	Very tasty. Can't taste any protein at all.
25%	In this one, you can see and feel (mouth) the high barley content, the viscosity has been increased, besides this, is still acceptable, the colour is darker but no undesirable
25%	a sugar cookie should have sugar in it_
25%	good flavor and good texture - not too chewy, 259 was the best sample though
25%	good mix of sweetness and nutiritive value
25%	less grain flavour, but it is still there
25%	more flavour than the last 3, still kind of bland
25%	It was good. A little chewy like 463.
25%	flavor is a bit unpleasant, texture is a bit heavy
25%	flavor not quite as good as previous
25%	flavor less intense than last sample
25%	slightly malty taste, a little bland but tastes fine
25%	I can tell that this cookie is not made from refined flour. The barley gives it a 'rustic' taste.
25%	dislike the color, but the taste is ok
25%	Texture good. Lacking in flavour. Like Slightly!
25%	cookie had light texture and was good
25%	has a bit of a strong aftertaste
25%	good but still has an after taste
25%	when chewed it becomes quite gooey and sticky
25%	Good but not as chewy as 511.
25%	slighty sweet, kind of like a simple digestive cookie
25%	I like how it's a little soft and chewy.
25%	It's a bit plain in flavour. Almost like I'm actually eating flour.
25%	aftertaste was not as strong but still present to a degree
25%	dry
25%	I can taste the Barley but I can also taste some sweetness.
25%	barley aftertaste not prevalent = GOOD
25%	not sweet enough, pastey in my mouth, tastes a bit yeasty?
25%	liked this cookie better than 993
25%	a rather non-descript cookie, similar in taste to sample 259, but a bit more moist
25%	Not a lot of flavour. Would be a better dcookie with chocolate chips.
25%	Tastes a bit off
25%	cookiw was moist little a bit but taste-wise it's ok

25% sweet
30% sweeter and less crumbly than the first one (#511)
30% it smelled better than 463_
30% nice slightly sweet
30% Nice crunchier texture, not very sweet, cute appearance.
30% better than last two_
A light cookie. It has the yummy cookie aftertaste as well. I like the appearance. The rich golden brown of the bottom of the cookie is appealing. A little bit crumbly
30% but still soft and nice and chewy. Quite appealing. This seems like a good snack c
30% the texture was stickier and chewy
30% leaves aftertaste...
30% Tasted alright, and texture was okay.
30% salty, doesn't taste like a cookie
30% oaty aftertaste_sticks to my mouth roof
30% better testure than #993 and 776, but not very much flavor or sweetness
30% nice n crunchy, yet not dry._dont taste the baking soda any more._Good flavor.
30% slighty bitter tasting after chewing, wheat-like aftertaste
30% sticks to teeth after chewing
The taste of baking soda is a little strong, but it has a buttery flavour which is nice.
30% Texture is slightly grainy, but not bad. I'd eat this cookie again;)
30% Leaves a 'slimy' feeling in mouth after chewing the cookie
30% it's not crispy_
30% texture was good, but it had an odd flavour. An corn after taste still can be percived
Aside from the colour and the slightly 'caramel' flavour, this cookie is comparable to
30% 148. Note that the texture is less crumbly.
not as bad as some, but defininetely not good... so yeah... lingering taste...thank
30% gawd for club soda!
30% not quite as well-flavoured as previous cookie, but still good.
30% not crispy enough (sticks to your teeth too much)
30% 897 has the same characterisitcs as 625
30% about as good a cookie as any of the others, or better
30% not sweet enough - reminds me of something, but can't think of what
30% Fairly average cookie.
30% no flavor. ik!
The cookie is slightly sweet but not cloying. I feel like this would be a good quick
30% snack if I just wanted something sweet after lunch or after supper.
30% if bland cookies were wrestlers, this one would be Hulk Hogan.
A little bit sweeter than 993 however, there is still a bit of that aftertaste that I find not
30% that desireable._
30% Tastes decent. No bad aftertaste. However, the taste does not grab you.
30% less after taste. actually, taste good. not too sweet.
30% Really like the texture of this cookie. Not too crisp and not too chewy.It was good!
30% It might be a little sweet, depends on the person.
30% kinda sticky
30% a little bit salty
Felt like a lighter texture. Still sticks to teeth after chewing. Seemed slightly
30% sweeter. Flavor is like a digestive or arrowroot cookie. Tasty cookie!
30% Kind of stale tasting, too 'thick', not as smooth.
30% leaves sticky cookie in my teeth
30% this one was the least barley flavored cookie. I enjoyed this one the most becasue it

	did not have an aftertaste.
30%	texture too sandy, slight bitter taste
30%	very bland tasting, left aftertaste in my mouth
30%	Tasty
30%	Better flavor, some sweetness, better than before, still viscous.
30%	bland_
30%	decent flavor, a bit oily, melts in mouth
30%	a bit of a negative intermediate taste. Somewhat similar to 511 of 463
30%	I like the texture. Nice amount of sweetness.
30%	Again, too much grain flavour. A bit gummy in texture._P.S. I found the club soda very hard to drink and would have preferred just water._
30%	Not too different from the first.
30%	It smells cereal.
30%	texture is nice - a bit crunchy, but it has a bit of after taste that is unusual
30%	not as tender as 259, barley flavor slightly stronger
30%	good taste & texture
30%	can't tell much difference between this one and the previous, #993. Except that maybe this one was a bit crunchier._
30%	dillke the brown color_the taste is ok, but I won't purchase it.
30%	Like flavour but too oily - enjoyed chewy texture
30%	this cookie was good. had a hint of burnt flavour.
30%	Similar to sample 259: reminds me of a 'whole Wheat' shortbread cookie
30%	this one was the best though there was a slight residue feeling in the mouth
30%	becomes gooey when chewed (like 625) and has a bitter/off after-taste
30%	Sweet but not overly. Does not have a strong taste of barley!
30%	bitter
30%	this one didn't have much taste. slight sweetness, but that is all
30%	Rich in the grain used. I like it.
30%	I didn't like the texture of this one very much
30%	
30%	bitter
30%	Not very appetizing to the palate. Had the crunch of a shortbread cookie though.
30%	same as cookie sample #625
30%	897 tasted very much the same as 625
30%	Reminds me of those low-cal cookies that really don't have very much flavor.
30%	Seems like a shortbread
30%	I coudn't really taste much difference between 993 and 897 - maybe a little less salty?
35%	pretty good but a bit of a bitter taste
35%	it had an unpleasant odour__
35%	I personally think I can eat any of the cookie samples. All tase good in different ways
35%	tastes the exact same as 897
35%	fine cookie
35%	Cute appearance. Texture ok, and moderate sweetness.
35%	no good
35%	I like the strength of the flavor. It seems very rich, and the cookie is also nice and soft. It tastes relatively healthy (a good thing. I like the appearance, its colour makes it rather appetizing.
35%	salty

35% less aftertaste_its ok
35% didn't have a lot of flavour
35% Nice taste! good texture overall.
35% good texture_tastes the baking soda._needs better flavor.
35% not sweet, bitter tasting_
35% Nice flavour, but seems to stick to the top of your teeth
I can't quite put my finger on it, but I'm not really fond of this cookie. It tastes fine, but not as good as some of the others. It almost has a grittiness to it too, and a little
35% tougher texture.
35% Texture is similar to 511, but taste is slightly better.
35% Texture was not nice. A corn-like after taste is present
35% Not as crispy as a drop sugar cookie should be.
35% Similar to 625, sharper burnt flavour and a little more soapy feeling on the tongue.
again i found this cookie to have very little taste... almost too much like a quaker
35% cereal... like quaker cereal but its just that this cookie was a tad bit tasteless....
35% slight aftertaste, and not as sweet as I would have liked
35% 463 has the same characters as 625
35% a little bit of flavor (not huge amounts)
35% fairly bland, but not repulsive
not bad, but probably would not buy it given the choice. again, tastes a little too
35% much like a sugar cookie.
35% Needed a little more sugar.
35% more chewy_
35% This cookie tastes like stale popcorn with icing sugar on it. I don't like it.
35% it tastes like the bottom of a shoe. Don't ask me how I know.
35% Strong aftertaste
35% Nice Texture_Again, the aftertaste is a bit... slimy.
35% sliminess is there. color is a bit too dark, which is strange for normal cookie
35% I liked the texture of this cookie
35% a little bit salty
35% nice texture, seemed to be more gummy, it stuck a bit more to my teeth.
35% kind of heavy. Not as smooth as previous one.
35% gummy, sticks in my teeth, greasy mouth feel
35% it has a barley flavor to it but it is nto too strong that it drowns out the sugar flavor.
35% was a little softer in texture,light tasting, leaves a bits of an aftertaste in mouth
Very bad texture, and does not have a good flavour. It leaves a bad after taste as
35% well.
35% stick to teeth, aftertaste
35% This was better than the last cookie, is still viscous but I liked the flavor.
35% better than the last one I ate_
35% bitter aftertaste
35% less negative intermediate taste than 511
35% Has a baking-soda like taste to it.
35% quite bland - only flavour is grain
35% very bland tasting
35% Has a bit of an after taste.
35% a bit salty
35% texture OK, after taste OK, somewhat sweet
35% flavor could be a little bettter. perhaps a bit dry--is dry but i tend to like some cookies

	a little dry but would probably prefer thid one a little moister.
35%	quite tender, some whole wheat flavor
35%	better texture, a little pasty at the end, tastes fine
35%	Better than the last. Not as salty, although personally I'd prefer less salt and more sugar.
35%	don't like the brown color_a little dry,_don't like the flavor
35%	Texture too gooy - dont like after taste and film it leaves in mouth.
35%	it didn't have very much taste to it. but it had just the right sweetness.
35%	Reminds me of a 'diet' cookie - slightly bland
35%	gooey when chewed
35%	It has a corn kind of taste, almost like that 'corn squares' cereal by Quaker
35%	I like how it's light and sort of melts in your mouth. It tastes kind of plain though.
35%	Tastes like 625, but with a pinch of salt._Thanks for the study!
35%	So far this one is my favourite
35%	funny aftertast_
35%	bit bland
35%	First tastes like a regular cookie and then the Barley hits you.
35%	same as cookie sample #625 and #897
35%	this cookie has a distinct flavor but tasted ok
35%	Similar, but slightly better than samples 776 and 897.
35%	too sticky and strong aftertaste ?
35%	Not alot of taste to it.
35%	A bit dry compared to 625
37.50%	chewier but has less flavor
37.50%	tastes similar to the previous 2 cookies but there is something slightly sticky about this cookie and a weird aftertaste....
37.50%	
37.50%	Cute appearance._This cookie is a little softer than sample #511, better texture.
37.50%	Reminds me of shortbread.
37.50%	tastes like rasin bran or shreddies cereal
37.50%	Very crumbly. Not as soft as other cookies. Not a real fan of the utter sweetness of this cookie, is slightly unsettling. Still a decent cookie, but not as delicious as an oatmeal cookie. Too sweet for a plain sugar cookie, not the right type of sweetn
37.50%	less of a barley taste
37.50%	contained some bitterness in the cookie.
37.50%	salty
37.50%	Salty, does't taste like a cookie
37.50%	fairly strong aftertaste_a little dry_
37.50%	not as dry as some of the others
37.50%	It is a little bland, not too much taste.
37.50%	still tastes the baking soda._needs more flavor._similar to the 463.
37.50%	texture soft...almost too soft, not too bitter
37.50%	chewy but crispy, does not come apart easily when bitten. Leaves a slimy feeling in the mouth
37.50%	It isn't as sweet or buttery as 511, this gives it a 'healthy' sort of taste... the kind that would make me not feel so guilty as I devour a bag of them in front of my TV :P
37.50%	better than 463.
37.50%	It's not crispy
37.50%	Crunchy texture is important to me, and this cookie was not crunchy. A corn-like after taste was perceived.

37.50% Too firm, dislike aftertaste.
37.50% This cookie is not crumbly, slightly bitter and extremely soapy. Its the worse of all of them.
37.50% gross..... almost spit that one
37.50% Has more of an aftertaste; perhaps the barley protein flavouring is not as subtle here.
37.50% has a softer texture then 625 and the 'whole-grain' tast isn't as pronounced, but 776 still tastes good
37.50% pasty texture; no flavor compared to 934
37.50% not sweet enough
37.50% a BIT DRY AND INITIALLY ODDLY CHEWY, BUT GOOD AFTERTASTE
37.50% I'm ambivalent about this cookie. It tastes fine. Not great but not bad. It's a little bit soft but not too pasty.
37.50% I think you put in too much suck in these cookies. You need more not suck.
37.50% Has somewhat of a strong bitter aftertaste and is not sweet enough
37.50% Weird Texture. Strange filmy taste.
37.50% Sticky, gummy, don't like the texture very much
37.50% it has slimy taste and is too soft.
37.50% Too salty! It was also very sticky, stuck to my teeth and gums! Unpleasant aftertaste as well
37.50% it's not tasty, too soft and salty
37.50% strong cereal flavor.
37.50% tastes stale, heavy and too 'thick'. Does not have a good flavour._
37.50% this one was not crispy enough, it was a bit too soft, stale like.
37.50% nice even flavor. It has a bit of a 'grainy' aftertaste
37.50% bad taste, more dense texture, not very sweet tasting
37.50% It has a strong protein taste, like protein supplement powder, kind of dry. Not bad though.
37.50% sticky
37.50% The sweet flavor has been minimized, it is a little salty and really viscous, its everywhere in my mouth (sticky) like a chocolate...still is not at all bad
37.50% bland
37.50% chewy, bad aftertaste
37.50% a bit bland
37.50% very grainy in flavour. Had very little texture - just sort of disintegrated!
37.50% bland, not much taste, kind of a wierd texture
37.50% Nice taste.
37.50% heavy texture, somewhat oily, not very sweet
37.50% prefer 897
37.50% flavour seems too intense
37.50% has a pasty aftertaste & feel (texture)
37.50% Also quite salty - this, unfortunately dominates all tastes. However, the wild, grainy or rustic taste (as I'm calling it) is still present. That's not a bad thing, but might take some people some time to get used to.
37.50% don't like the brown color
37.50% Good taste - not a bad texture
37.50% it had a funny salty taste at the end
37.50% leaves a bit of a slightly unpleasant 'gummy' residue
37.50% a strong after taste and a feeling of residue in the month
37.50% gooey and very bitter/sour after taste
37.50% Strong barley taste. Will leave and after taste in mouth.

37.50%	This one has a corn taste & has a more buttery taste
37.50%	It was kind of hard and crunchy. It tasted very plain.
37.50%	Boring. Wouldn't buy it. But a type that would go at a reception.
37.50%	It tasted alright, but had a strong after-taste
37.50%	has a baking soda after tast that is not enjoyable
37.50%	Not very plesant. Coats the entire mouth with fibre and feels like eating breakfast instead of a treat.
37.50%	aftertaste of barley quite stronger than #934
37.50%	this cookie tasted very similar to 993 but not as strong flavored
37.50%	VERY similar to sample 897
37.50%	dont like the aftertaste
37.50%	seems almost like almonds
37.50%	Much chewier texture
40%	kind of bitter
40%	kind of bland, strange aftertaste
40%	taste is ok but it is kind of chewy and has an aftertaste
40%	Cute appearance. When first bitting into the cookie, the texture seems funny - too tough, or too carmelized on the bottom.
40%	too much liek cereal
40%	A little bland, but yummy! No unsettling flavor. This would make a great snack food on a regular basis! The colour was good and dark, and it seemed soft and chewy. Also not overly crumbly or breakable so could be transported in lunches easily. I liked
40%	it was dry and tasted like baby cookies
40%	Just a little gummy, and a flour taste
40%	nice appearance_a little more baked than the others_sticks to my mouth roof
40%	inital taste is ok, slighty salty but then it tastes bad
40%	This cookie taste good, like the overall taste.
40%	tastes the baking soda, weird flavor, a tad salty. Have a heavier texture.
40%	leaves bitter aftertaste in mouth, texture between soft and crunchy
40%	leaves a slimy feel in mouth, and seems brittle when you bite into it
40%	I like this one well enough. It is much better than 463. It is sweeter and has a better texture (not as tough. flakier maybe?) Pretty good.
40%	has a strong grainy flavour
40%	Texture was not crunchy and it had an after taste similar to corn
40%	Dislike aftertaste.
40%	I like the taste of it. The texture is a little more firm and its stick a little more to the teeth.
40%	found it to be tasteless...
40%	some aftertaste, and slightly grainy texture
40%	511 has the same characteristics as 776, but not as good as 776
40%	Chewy!
40%	quite pasty and dry
40%	not very good at all ... cookie monster would barley eat that one
40%	needs more sugar
40%	way too salty
40%	This cookie tastes bland and almost salty. It leaves a coating in my mouth that is very unpleasant. The taste at the back of my throat is salty and gross.
40%	the aftertaste was NAAAAAAAAAAAST-AY.
40%	Bitter aftertaste

40% It has a bad aftertaste of baking soda
40% it has strange after taste. not bad interms of mositure.
Quite chewy and somewhat stuck in my teeth. Not as sweet as the other cookies.
40% Salt content was adequate
40% I did not like the after taste
40% too salty and soft
40% strong cereal flavors, similar to a digestive cookie
40% Tastes kind of stale.
40% too much flavor- too 'grainy' tasting. texture a littel too hard. Dense.
did not leave much of an aftertaste in my mouth, very neutral tasting, light in taste
40% and texture-good
40% Very bad texture, does not feel good in the mouth. Very bad after taste.
40% sticky, some aftertaste
40% Too viscous, salty, where is the sweetness?
40% still ahs a little aftertaste
good initial and aftertaste, but the intermediate taste is a bit bland (like other high
40% plant protein foods)
40% Texture is okay, but a bit too strongly tasting
40% again, quite bland and major flavour is grain
40% Similar to 625. Has a bit of an aftertaste too but not totally unpleasant.
40% there was something thickening in my mounth after chewing.
40% texture seems a bit heavy and oily, not very sweet
i answered the last question toofast .. after i swallowed the whole thing it tasted off
40% flavor.-- dislike slightly would have been a better answer.
40% sl barley flavour
the cookie has a pasty texture just after starting to eat it, it feels like a gluey
40% substance
40% far too salty
40% Dislike the dark brown color and flavor_
40% odd texture - not a great after taste
40% this cookie has a different flavour. almost burnt.
40% On the bland side, very slight 'gummy' feeling after eating.
40% after taste did not seems as strong
40% gooey and bitter
40% Strong barley taste and salty!
40% tastes more like a breakfast cereal than a cookie. Has a heay/buttery feel
40% this cookie tastes very bland and sort of bitter.
40% Tastes just like the last cookie (sample 897) but with a bit of salt added to it.
40% good till the aftertaste
40% starchy
40% Tastes like cereal and clings to the teeth.
40% Very good, I would eat those on a regular basis.
40% this cookie had a stronger flavor than 463, didnt like it as much
40% Maybe too much baking powder? Definately not enough sugar.
40% too sticky +aftertaste
40% not as fresh as the others or maybe over done._
40% Nice combination of texture and taste
40% too moist and flat in taste
40% less sweety

45% sweet and chewy, good
45% it tastes like I'm eating hay
okk cookies can truly taste bad - i didn't like this one too much - taste was different
45% than previous ones and left a strong aftertaste
45% liked the texture - crunchy. Fairly sweet, but not a very good afer taste.
45% same as last - too breakfasty
Dry. Somewhat unsettling. But not too overly sweet. A good snack cookie although I'd probably prefer arrowroot biscuits or oatmeal or peanut butter cookies. Maybe
45% icing would mask the unsettling flavour?
45% stickier texture comparedto first cookie
45% Did not like the taste, ended up being very pasty or gummy
45% salty
45% Salty, doesn't taste like a cookie
45% sticks to my mouth_tastes like cereal - oat bran or something_worse aftertaste
45% strange, chewy texture
45%
45% It has a strong barley after taste.
a little salty, a weird flavor to it- kinda similar to that baking soda taste. Don't like the
45% flavor as much.
45% very bitter tasting. not sweet at all
45% tastes oily, leaves a slimy mouth feel afterwards
I like this one. It doesn't seem to be as sweet as the other ones; it tastes 'healthier'. It tastes very good though. Texture is nice; crunchy/crispy (not too sure how to
45% describe)
45% Too sticky and a strong corn-like after taste was present
45% A strong lingering aftertaste to it! Very soapy!
45% Some aftertaste; could be sweeter as well.
45% about the same as 776, but a bit tastier.
45% Not as good as the first sample (148)_
45% a little pasty
stuck to the top of my mouth ... wasn't too great. unlike pepsi which is undeniably
45% great
45% reminds me of breakfast cereal. needs to be sweeter
45% Yuck.
45% not a noticeable difference_
I imagine this is what dry grass would taste like. After chewing for a bit, there was a
45% pasty, lardy taste in my mouth.
45% bland like boy bands.
Good texture (i.e. nice chewy texture) however, there is a strong aftertaste that I
45% would not normally associate with cookies.
45% A bit too chewy.
45% It also has some aftertaste and sliminess otherwise good
45% sticky in my teeth and an unpleasant aftertaste
45% too salty and soft
Slightly sticks to the teeth after completely chewing. Flavor of barley not as strong.
45% Nicer appearance (color)_
45% Don't like the texture. It does not taste fresh. Taste stale and the flavor is obscured.
45% gummy, funny flavor, sticks in teeth
45% tastes very similar to 463. It is a bit less sweet.
45% Bitter taste

45% very dry taste
45% Lacking of flavour.
45% less sweet, aftertaste
Too salty, it is crunchy but thats good, there is no sugar on this one? Acceptable
45% colour, viscous but not bad...
45% the first 2 bites were good, the last 2 less so_
45% can taste the barley, bad aftertaste
45% not quite enough sucrose for my tastes
The texture is too pasty and almost tastes like it has too much baking soda or
45% something in it. Yuck. 897, 776, and 934 were the best ones.
45% gritty, bitter
45% Not bad at all.
45% After been chewed, its texture was like past stick in my mouth.
45% a bit heavy and oily, after taste not sweet
i ate the whole cookies in this set. maybe i should have done the same with last set
for more accurate answers. I kept feeling like i was tasting the club soda while i was
45% sampling the cookies. i wonder if it would be good to eat something like a piec
45% the cookie is bitter, and has an unpleasant first taste
this cookie is softer. I enjoy soft, moist cookies but this one is a bit drier than my
45% ideal.
45% A little bit dry and a little salty
45% Too much baking soda - leaves gooy feeling in mouth.
i didn't like the flavour. it tasted kinda burnt and salty. the texture was not as light as
45% 148. it was a more dense cookie.
45% slightly chewey, strong, slightly unpleasant aftertaste
45% texture was different and a after taste
45% goopy when chewed and bitter/sour flavour
45% Strong taste of barley. Will leave an after taste in mouth.
45% tasted bitter, like a burnt cookie
45% kind of bitter tasting & has a corn flavour. It sticks to my teeth as well
45% It tasted a lot like cookie #776 which I found to be neutral(didn't like or dislike).
It has rich flaour in the type of grain used. Not sweet or salty, great for babies
45% developing teeth (if softer)
I didn't really like the taste of this one (it didn't taste bad, it just wasn't that great) but
45% It's the texture that I really didn't like
smells funny, Since I can't go back and comment about 148, I will say that it has a
45% pleasing apperance and texture_
45% Really thick and chunky texture.
45% this cookie is not as sweet as 259 but tasted ok
45% the cookie isn't very sweet, and it's rather hard
45% too sticky and more salty? don't like taste
45% Yuck. Discontinue this series. Made the soda water taste good.
45% It is less sweet than many other cookies I have eaten, but I think I rather like that.
45% It looks like more nutritional
45%

Appendix 5 Consumer scorecard for blind evaluations for Group 1.

Please take another sip of club soda to clear your palate.

Sample 259

Look at and smell the cookie on the plate in front of you.

- **Appearance**

Overall, what is your opinion of the appearance of this cookie?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

- **Aroma**

Overall, what is your opinion on the aroma of this cookie?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Eat a mouthful of the cookie.

- **Flavour**

Overall, what is your opinion of the flavour of this cookie?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

- **Texture**

Overall, what is your opinion of the texture of this cookie?

❒	❒	❒	❒	❒	❒	❒	❒	❒
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

- **Overall opinion**

Overall, what is your opinion of this cookie?

❒	❒	❒	❒	❒	❒	❒	❒	❒
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

If you have any comments on this sample of cookie, please record them below:

_____

_____

_____

Please answer the demographic questionnaire.

Please raise your hand to indicate you are ready for your second set of cookies.

Appendix 6 Demographic questionnaire.

Consumer Demographics

Please take a few moments to answer some questions about yourself

1. What is your gender?
   - ❒ Male
   - ❒ Female

2. What is your age range?
   - ❒ Less than 20 years
   - ❒ 20 to 30 years
   - ❒ 31 to 40 years
   - ❒ 41 to 50 years
   - ❒ 51 to 60 years
   - ❒ 61 +

3. Do you consume cookies?
   - ❒ Yes
   - ❒ No

3a. How frequently do you consume cookies?
   - ❒ Daily
   - ❒ Several times per week
   - ❒ Once per week
   - ❒ Several times per month
   - ❒ Once per month
   - ❒ Never

5. Do you read nutrition information labels?
   - ❒ Yes
   - ❒ No

5a. If so, how important are nutrition labels to you?
   - ❒ Extremely important
   - ❒ Very important
   - ❒ Somewhat important
   - ❒ Neither important nor not important
   - ❒ Not important
   - ❒ Not important at all

Thank you for answering these questions.

Appendix 7 Group 2 specific nutrition information

Please read the Nutrition Information Sheet before evaluating the second set of cookies.

Nutrition Information Sheet

Soy:
According to Food and Drug Administration (FDA) in the United States, diets low in saturated fat and cholesterol that include 25 grams of soy protein a day may reduce the risk of heart disease.

One of these soy cookies provides 3.9 grams of soy protein.

Oat:
Cereal based proteins especially from oats may be part of a healthy diet low in saturated fat and cholesterol.

One of these oat cookies provides 2.5 grams of oat protein.

Recent research studies at the University of Alberta are investigating the potential applications of oat protein in various food products.

Barley:
Cereal based proteins especially from barley may be part of a healthy diet low in saturated fat and cholesterol.

One of these barley cookies provides 2.5 grams of barley protein.

Recent research studies at the University of Alberta are investigating the potential applications of barley protein in various food products.

Appendix 8 Group 3 general nutrition information

Please read the Nutrition Information Sheet before evaluating the second set of cookies.

Nutrition Information Sheet

Soy:
These cookies contain approximately 3.9 grams of soy protein/serving.
(~ 6 cookies/serving)

Oat:
These cookies contain approximately 2.5 grams of oat protein/serving.
(~ 6 cookies/serving)

Barley:
These cookies contain approximately 2.5 grams of barley protein/serving.
(~ 6 cookies/serving)

Appendix 9. Cookie evaluation scorecard

Cookie Evaluation Scorecard

You have three labeled samples of cookies in front of you. Evaluate the samples in the order shown below.

Please clear your palate before you begin with a sip of club soda.

Sample _____

Look at and smell the cookie on the plate in front of you.

- **Appearance**

Overall, what is your opinion of the appearance of this cookie?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

- **Aroma**

Overall, what is your opinion on the aroma of this cookie?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Eat a mouthful of the cookie.

- **Flavour**

Overall, what is your opinion of the flavour of this cookie?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

- **Texture**

Overall, what is your opinion of the texture of this cookie?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

- **Overall opinion**

Overall, what is your opinion of this cookie?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

If you have any comments on this sample of cookie, please record them below:

_____

_____

_____